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ALT Space Shuttle Barometric Altimeter

Altitude Analysis

Mission Planning and Analysis Division

June 1978

(NASA-TM-79528) ALT SPACE SHUTTLE
BAROMETRIC ALTIMETER ALTITUDE ANALYSIS
(NASA) 70 p HC A04/MF A01

CSCL 14B

N78-25126

Unclas
G3/19 22770



National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas



78-FM-22

78FM22

JSC-13937

SHUTTLE PROGRAM

ALT SPACE SHUTTLE BAROMETRIC ALTIMETER

ALTITUDE ANALYSIS

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June 1978

ACKNOWLEDGMENTS

The author wishes to thank Linda F. Smith of MPAD for help in acquiring and tabulating data from Captive Active 1, Captive Active 3, and Free Flight 1.

Definition of Variables and Abbreviations

SGMT	Site time (Greenwich mean time) hr:min:sec or sec
DFI	Altitude measured by Orbiter noseboom altimeter
OI	Altitude measured by Orbiter sideprobes
SCA	Altitude measured by the Shuttle carrier aircraft air data system
Kalman	Altitude determined from C-band radar data processed through a Kalman filter with refraction correction
True	Altitude determined from balloon data
DFRC	Altitude determined from C-band radar data not corrected for refraction
Corrected OI	OI corrected for nonstandard day effect
Corrected DFI	DFI corrected for nonstandard day effect
Theodolite	Altitude from least squares solution to phototheodolite data with refraction correction
RA	Altitude from radar altimeter data
MSBLS	Altitude from microwave scanning beam landing system
Standard	U.S. Standard Atmosphere of 1962

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ALT SPACE SHUTTLE BAROMETRIC ALTIMETER**ALTITUDE ANALYSIS**

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1.0 SUMMARY

This analysis has been performed to determine the accuracy of the barometric altimeters onboard the Space Shuttle Orbiter. Altitude estimates from the air data systems including the operational instrumentation (OI) and the developmental flight instrumentation (DFI) were obtained for each of the approach and landing test (ALT) flights. By comparing the barometric altitude estimates to altitudes derived from radar tracking data filtered through a Kalman filter and fully corrected for atmospheric refraction, the errors in the barometric altitudes have been shown to be 4 to 5 percent of the Kalman altitudes. By comparing the altitude determined from the true atmosphere of date derived from weather balloon data to the altitude determined from the U.S. Standard Atmosphere of 1962, it was determined that the assumption of the Standard Atmosphere equations contributes roughly 75 percent of the total error in the baro estimates. After correcting the barometric altitude estimates using an average summer model atmosphere computed for the average latitude of the Space Shuttle landing sites, the residual error in the altitude estimates was reduced to less than 373 feet. This corresponds to an error of less than 1.5 percent for altitudes above 4000 feet for all flights except free flight 5 which was flown on October 26, an autumn date. Most of the error remaining after correction for nonstandard day effects was shown to be due to the static defect caused by imperfect modeling of air flow into the air data system. This error was less for the DFI data that were obtained from air data probes on the noseboom than for the OI data that were obtained from the sideprobes on the fuselage.

2.0 INTRODUCTION

This design note presents the results of a study intended to determine the accuracy of the barometric altimeters onboard the Space Shuttle Orbiter. Actual flight data were obtained from the Orbiter noseboom and the Orbiter air data system (OI) as well as from the Shuttle carrier aircraft (SCA) barometric altimeters. These data were compared to altitude estimates derived from C-band radar data processed through a Kalman filter at the Johnson Space Center (JSC) and fully corrected for atmospheric refraction. The radar estimates are referred to as the Kalman altitude estimates. In order to determine the difference between the actual atmosphere of date and the U.S. Standard Atmosphere of 1962, data were obtained from weather balloons flown concurrent with each flight. These data were in the form of atmospheric pressure versus altitude. The errors in the Kalman altitude estimate were assessed by comparing these data to data obtained from phototheodolite tracking instruments, radar altimeter, and the microwave scanning beam landing system.

3.0 DISCUSSION

3.1 ERROR SOURCES

The OI measures pressure at the pitot tubes on each side of the fuselage, and the developmental flight instrumentation (DFI) measures pressure at the noseboom. The sources of error in the measurements include uncorrelated errors in the measurement of pressure and time delays in the air data system. Reference 3 documents the total uncorrelated random error due to instrument noise for free flight 4, which results in an altitude error of 1 to 1.5 feet. According to reference 1, time delays in the OI should be less than 0.5 second if specifications are met and should not contribute significantly to the total error. Therefore, it is concluded that the air data system makes very accurate measurements. However, in order to determine the altitude from the atmospheric pressure, the onboard computer uses an atmosphere model defined by the "U.S. Standard Atmosphere of 1962," which is an average atmosphere for the continental United States. This model assumes that it is given a value of static pressure and further assumes that the static pressure varies with altitude in a certain way. Each of these assumptions results in an error. The true atmosphere has diurnal, seasonal, latitudinal, and weather-related variations. The error referred to as the nonstandard atmosphere error reflects the difference between the true atmosphere of date and the standard atmosphere. The "U.S. Standard Atmosphere of 1962" may be referred to for further discussion and graphs showing seasonal variations in the atmosphere. As the craft moves through the atmosphere, the pressure measured at the pitot tubes differs from the static pressure, resulting in the error referred to as the "static defect" error. The static pressure coefficient, a measure of this error, is modeled using data from wind tunnel tests and provided to the onboard computer. However, errors in the wind tunnel instruments and differences between actual flight conditions and simulated conditions result in a residual static defect error.

3.2 PROCEDURE

Three barometric altitude estimates were obtained from hard copies taken from the display consoles for the ALT flights including DFI and OI. The flights are described as captive active 1A (CA1A), June 18, 1977; captive active 3 (CA3), July 26; free flight 1 (FF1), August 12; free flight 2 (FF2), September 13; free flight 3 (FF3), September 23; free flight 4 (FF4), October 12; and free flight 5 (FF5), October 26. The Orbiter air data appearing on the display were converted to mean sea level (MSL) units as follows. Let X be the number appearing on the display and h the MSL altitude.

$$h = 5X + 1256 \quad X < 500, \text{ ft}$$

$$h = 50X - 21244 \quad X \geq 500, \text{ ft}$$

The SCA and DFI data were displayed as MSL altitude.

An independent estimate of the altitude was obtained from a trajectory calculated using a Kalman filter to process FPS-16 C-band radar data from Dryden

Flight Research Center (DFRC). Uncorrelated measurement error statistics were set at 0.2 mrad for azimuth and elevation and 30 feet for range. Refraction corrections were applied to the measurements. These data will be referred to as the Kalman estimate. The Kalman geodetic altitude can be converted to MSL units by subtracting 51 feet from the Kalman altitude. All barometric altitudes are referenced to MSL.

In order to determine the error in the barometric altitude estimates due to the fact that actual atmospheric conditions may vary from the standard, air data were obtained from weather balloons flown concurrent with each flight in the vicinity of Edwards Air Force Base. The "true" altitude at a given pressure was obtained from the solution to the upper air data reduction program performed at DFRC. The data used for this report was derived from balloon flight data labeled 15:30 hours GMT on the date of each flight. The error in the barometric altimeter readouts due to the nonstandard day effects was determined by taking the difference between the altitude given by the DFRC solution at a given pressure and that given by the 1962 Standard Atmosphere tables for the same pressure. These differences were plotted versus the true, or balloon, altitude for each flight and are labeled "62 Standard Minus True Altitude."

All of the barometric altitudes were compared to the Kalman altitude estimate, which was considered the truth model. In order to verify the accuracy of the Kalman estimates, they were checked against altitude estimates determined from phototheodolite data, radar altimeter data, and microwave landing system data. In addition to radar tracking, the Orbiter was tracked by a system of phototheodolite instruments. A least squares solution for the Orbiter's position was obtained at DFRC from phototheodolite data fully corrected for refraction. Differences were taken between the theodolite and Kalman estimate of the runway 17 Z coordinate since the estimated altitude was not available, based on the phototheodolite data. Delta Z was plotted versus the Kalman estimate of altitude above runway 17 for free flights 1, 3, 4 and 5. Free flight 2 was not used because the data were in runway 15 coordinates.

Radar altimeter data were available for free flight 1 for altitudes below 5200 feet. The difference between the Z component of position estimated by the radar altimeter and the Z component of position estimated by the Kalman solution to the radar data is plotted versus the Kalman altitude above runway 17 in figure B-1. This graph is not corrected for a 15-foot difference between the vertical component of position in the Orbiter's body coordinate system of the radar altimeter antenna and the C-band radar antenna. The antenna positions in body coordinates are given in table I for all of the onboard antennas. The difference between the radar altimeter and Kalman estimates at an altitude of 5000 feet is 28 feet. Adding a 15-foot bias results in a total difference of 43 feet. After correction for the difference in antenna locations, the mean (μ) and standard deviation (σ) of the quantity (radar altimeter altitude minus Kalman altitude) are 29 feet and 9 feet, respectively. The standard deviation of 9 feet indicates the noise in the measurements, and the mean of 29 feet reflects a bias between the two estimates.

As a further check on the accuracy of the radar estimate, data from the microwave landing system (MLS) were obtained for free flight 1. The difference between the MLS estimate of altitude and the Kalman radar altitude estimate was plotted versus radar altitude above runway 17 (fig. B-2).

The quantity MLS altitude - Kalman radar altitude) has a mean and standard deviation equal to -1 foot and 18 feet, respectively, for altitudes between 1000 and 11 000 feet. At lower altitudes, the elevation angles were unreliable, and at higher altitudes, the MLS was out of range. These data were corrected for the antenna offset between C-band radar and the MLS antennas. Part of the noise in these data is due to the fact that the time tags on the range and elevation data from the MLS may have been 0.25 second apart. Therefore, the noise probably reflects the MLS data rather than the Kalman data. These data indicate that at low altitudes, the Kalman estimate is unbiased.

The difference between the phototheodolite estimate of Z and Kalman estimate of Z is plotted versus altitude for free flights 1, 3, 4 and 5 (figs. B-3 through B-6). These plots show a correlation of error with altitude. The maximum difference for altitudes above 4000 feet is 45 feet excluding obvious glitches, and the maximum difference for altitudes under 4000 feet is 30 feet including free flight 5 or 10 feet excluding free flight 5. The plots showing the difference between the barometric altitude estimates and the Kalman altitude estimates probably display the true error in the barometric altitude estimates plus or minus about 30 feet.

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4.0 RESULTS

The estimated error in the OI altitude, the DFI altitude, and the SCA altitude are plotted versus the Kalman altitude for each flight (figs. B-7 through B-23). On the same graphs are plots of the error in the barometric altimeter due to the nonstandard atmosphere (i.e., the difference between the 1962 Standard Atmosphere altitude and the true altitude). The data points for the Orbiter (separate from the SCA portion for free flights, or for the descent portion for captive active flights) are nonconnected; whereas, the data points for the mated portion of free flights, or the ascent portion of captive active flights, are connected to distinguish the two sets. The error due to the nonstandard atmosphere is plotted for each of the free flights in figure B-24 in order to judge the atmospheric variation over these 3 months.

For free flight 4 data, after separation of the Orbiter from the SCA, the mean and variance of the quantity $(OI - KALMAN) - (62 \text{ STANDARD} - \text{TRUE})$ are 12 feet and 12 135 feet², respectively. For $(DFI - KALMAN) - (62 \text{ STANDARD} - \text{TRUE})$ the mean and variance are 4 feet and 257 feet², respectively (fig. B-25). This gives an estimate of the statistics of the altitude estimates after correcting for nonstandard atmosphere error although the data are not a well-sampled normal distribution. For the OI altimeter, this gives a random error of 113 feet; for the DFI altimeter, the random error is 16 feet. The DFI and OI altitude estimates for free flight 1 were corrected for nonstandard atmosphere effects and plotted in figure B-26 and B-27, respectively. These plots graphically demonstrate the difference in noise between the DFI and OI data and show the magnitude of the errors after correction for the nonstandard atmosphere.

Reference 3 concludes that the maximum difference in static pressure between the left and right pitot tube for free flight 4 data after separation would result in a 100-foot difference in altitude reading for altitudes between 1700 feet and 9600 feet and a 170-foot difference for altitudes between 17 000 feet and 20 200 feet. These values agree reasonably well with the data presented here. Because the DFI measures pressure at the noseboom, slightly ahead of the spacecraft, it should measure a more uncorrupted value of static pressure than the OI, which uses an average pressure from the air data probes on the left and right fuselage. The flight data show that although the random error in the DFI data is less than that of the OI by a factor of 7, there is a residual error in the DFI estimate that varies in magnitude with altitude.

The data from the OI altimeter were more noisy than the data from the DFI altimeter; however, there was no appreciable difference in noise between the tailcone on and tailcone off configurations. This supports the conclusion of reference 3 that turbulence was not a principal error source.

The data points for descent show greater difference from the true altitude than for ascent but are closer to the error due to nonstandard atmosphere. The same trend was seen for the captive active and free flights ruling out the mated configuration as the cause. This indicates a greater static defect error for ascent; however, this is probably appropriate for the Orbiter.

These data also show that the static defect error is slightly less for the noseboom air data than for the OI, by about 100 feet.

The accuracy of the altitude estimates could be considerably improved if an atmosphere model more closely approximating the true atmosphere near the landing site were used. Various atmospheres have been calculated to account for seasonal and latitudinal effects. Reference 1 determined the root sum square error between the 1962 Standard Atmosphere and 10 nonstandard atmospheres for altitudes between 0 and 30 kilometers. This relation was fit with a least squares curve given by

$$\sigma_{ATM} = 1.891 \times 10^{-15} h^4 - 1.096 \times 10^{-11} h^3 - 2.579 \times 10^{-6} h^2 + 6.734 \times 10^{-2} h - 11.56$$

σ_{ATM} , h in meters

σ_{ATM} represents a one sigma error in the 1962 Standard Atmosphere based on these ten nonstandard atmospheres. σ_{ATM} is plotted versus Kalman radar altitude in feet in figure B-25. Comparison of figures B-24 and B-25 reveals that the σ_{ATM} curve falls within 300 feet of any of the nonstandard atmosphere error curves for the five free flights. Thus, if the 1962 Standard Atmosphere were corrected for seasonal and latitudinal effects using σ_{ATM} the residual error due to the atmosphere model at 30 000 feet altitude would be reduced from approximately 1300 feet to less than 300 feet, the error at an altitude of 16 000 feet would be reduced from approximately 800 feet to less than 300 feet, and the error at the ground would be unaltered.

The free flight 1 barometric altitude estimates were corrected for the error in the 1962 Standard Atmosphere using the true of date atmosphere. The differences between these corrected atmosphere estimates and the Kalman altitude estimates are plotted versus Kalman altitude in figures B-26 and B-27. These errors are less than 150 feet (excluding one data point) for DFI altitude estimates, and are less than 200 feet for OI altitude estimates. The OI altitude estimates were also corrected for errors due to the 1962 Standard Atmosphere using σ_{ATM} . The differences between these corrected altitude estimates and the Kalman altitude estimates are given in table II. These errors are less than 375 feet in all cases and are less than 300 feet excluding 4 data points. Thus, correcting the altitude estimates using σ_{ATM} is almost as good as correcting the altitude estimate based on the true of date atmosphere.

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5.0 CONCLUDING REMARKS AND RECOMMENDATIONS

The data presented from the ALT flights show that the errors in the barometric altitude estimates exceed the maximum allowable error of 3 percent of the altitude. From 70 to 80 percent of the error for altitudes above 4000 feet can be attributed to errors in the atmosphere model. The remaining errors are due to noise, calibration biases, and static defect error. It has been shown that by using an atmospheric model based on the season of flight and the mean latitude of the landing sites, the error in the barometric altitude estimates can be reduced to less than 2 percent of the altitude. Therefore, it is recommended that consideration be given to include corrections to the atmosphere model in the onboard software that include seasonal and latitudinal effects.

6.0 REFERENCES

1. Lear, Wm.: Baro Altimetry and Associated Error Models for the Space Shuttle. Mission Planning and Analysis Division, JSC IN 74-FM-83, December 10, 1974.
2. New Baro Altimeter Error Model. Mission Planning and Analysis Division, JSC Memorandum FM 83 (77-280), June 29, 1977.
3. Lear, Wm.: Letter to Paul Pixley, November 18, 1977.

TABLE I.- BODY COORDINATES OF ANTENNA SYSTEMS

Antenna	Coordinates, ft		
	<u>X_o</u>	<u>Y_o</u>	<u>Z_o</u>
C-band radar			
Upper	45.9	5.9	39.4
Lower	46.3	-8.0	24.6
Radar altimeter			
Forward	33.2	<u>+3.1</u>	23.9
Rear	37.8	<u>+3.2</u>	23.5
MLS			
Inboard	21.8	.34	30.8
Center	21.8	.73	30.7
Outboard	21.8	1.10	30.6
Air data probes	24.8	<u>+4.0</u>	26.9

TABLE II.- CORRECTED OI ALTITUDE MINUS KALMAN ALTITUDE, FT

<u>Geopotential altitude, ft</u>	<u>Flight</u>					
	<u>CA3</u>	<u>FF1</u>	<u>FF2</u>	<u>FF3</u>	<u>FF4</u>	<u>FF5</u>
4000	-1	167	132	53	-131	-39
8000	124	91	63	132	77	-56
12000	59	45	107	176	-50	346
16000	35	-12	148	145	-17	-114
18000	13	-55	201	-93	45	373
24000	40	-159	-246	-309	340	
28000	-231	-94				
30000	-178	-27				

APPENDIX A

ALTITUDE COMPARISON DATA TABLES (ALTITUDES IN FEET)

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TABLE A-I.- CAPTIVE ACTIVE 1A

<u>SGMT,</u> <u>hr:min:sec</u>	<u>SGMT,</u> <u>sec</u>	<u>DFI ALT,</u> <u>ft</u>	<u>OI ALT,</u> <u>ft</u>	<u>SCA ALT,</u> <u>ft</u>	<u>Kalman</u> <u>ALT, ft</u>	<u>SCA-</u> <u>Kalman,</u> <u>ft</u>	<u>SCA-</u> <u>true,</u> <u>ft</u>	<u>True</u> <u>SCA,</u> <u>ft</u>	<u>True SCA-</u> <u>Kalman ALT,</u> <u>ft</u>	<u>DFI ALT-</u> <u>Kalman,</u> <u>ft</u>	<u>OI ALT-</u> <u>Kalman,</u> <u>ft</u>	<u>Corrected</u> <u>OI-Kalman,</u> <u>ft</u>
14:56:19	53779.	2297	2326	2280								
15:18:32	55112.	13075	13145	12962	13462.6	-500.6	-555	13517	54.4	-387.6	-317.6	237
15:28:59	55739.	15147	15240	15020	15543.9	-523.9	-660	15680	136.1	-396.9	-303.9	356
15:29:00	55740.	15149	15240	15022	15568.0	-546.0	-660	15682	114.0	0419.0	-328.0	332
15:32:40	55960.	15198	15287	15065	15636.6	-571.6	-665	15730	93.4	-438.6	-349.6	315
15:36:56	56216.	15217	15295	15074	15632.6	-558.6	-665	15739	106.4	-415.6	-337.6	327
15:43:21	56601.	15231	15305	15077	15615.6	-538.6	-665	15742	126.4	-384.6	-310.6	354
15:48:55	56930.	15064	15149	14927	15557.8	-630.8	-660	15587	29.2	-493.8	-408.8	251
15:50:21	57021.	14953	15078	14838	15474.7	-636.7	-655	15493	18.3	-521.7	-396.7	258
15:50:59	57059.	14995	15084	14838	15477.6	-639.6	-655	15493	15.4	-482.6	-393.6	261
15:54:47	57287.	10005	10134	9828	10283.2	-455.2	-380	10208	-75.2	-278.2	-149.2	231
15:54:51	57291.	9837	9975	9655	10134.8	-479.8	-370	10025	-109.8	-297.8	-159.8	210
15:55:39	57339.	8079	8188	7915	8240.3	-325.3	-275	8290	49.7	-161.3	-52.3	223
15:55:52	57352.	7679	7816	7513	7761.0	-248.0	-250	7763	2.0	-82.0	55.0	305
15:57:03	57423.	5807	5896	5657	5846.0	-189.0	-160	5817	-29.0	-39.0	50.0	210
15:58:26	57506.	4965	5122	4838	4990.0	-152.0	-125	4953	-37.0	-25.0	132.0	257
15:59:39	57579.	3903	3996	3825	3923.2	-98.2	-80	3905	-18.2	-20.2	72.8	152

A-5

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TABLE A-II.- CAPTIVE ACTIVE 3

<u>SGMT, hr:min:sec</u>	<u>SGMT, sec</u>	<u>DFI ALT, ft</u>	<u>OI ALT, ft</u>	<u>SCA ALT, ft</u>	<u>Kalman ALT, ft</u>	<u>SCA- Kalman, ft</u>	<u>Error in 62 standard, ft</u>	<u>True SCA, ft</u>	<u>True SCA- Kalman ALT, ft</u>	<u>DFI ALT- Kalman, ft</u>	<u>OI ALT- Kalman, ft</u>	<u>Corrected OI-Kalman, ft</u>	<u>Corrected DFI-Kalman, ft</u>
14:46:40	53200	2186	2286	2158	--	--	--	--	--	--	--	--	--
14:47:25	53245	2181	2291	2145	2276.1	-131.1	--	--	--	-95.1	14.9	--	--
14:47:52	53272	2296	2476	2241	2333.4	-92.4	--	--	--	37.4	142.6	--	--
14:48:04	53284	2444	2621	2387	2463.0	-76.0	--	--	--	-19.0	158.0	--	--
14:48:38	53318	3104	3261	3040	3164.5	-124.5	--	--	--	-60.5	96.5	--	--
14:49:10	53350	3245	3451	3152	3337.5	-185.5	--	--	--	-92.5	113.5	--	--
14:49:56	53396	3943	4056	3869	4011.4	-142.4	-100	3969.	-42.4	-68.4	44.6	144.6	31.6
14:50:11	53411	4245	4206	4153	4337.7	-184.7	-125	4278.	-59.7	-92.7	-131.7	-6.7	32.3
14:50:31	53431	4659	4806	4588	4766.2	-178.2	-140	4728.	-38.2	-107.2	39.8	179.8	32.8
14:51:46	53506	6426	6556	6333	6631.6	-298.6	-245	6578.	-53.6	-205.6	-75.6	169.4	39.4
14:52:12	53532	7030	7156	6931	7262.2	-331.2	-275	7206.	-56.2	-232.2	-106.2	168.8	42.8
14:53:03	53583	7937	8106	7838	8209.1	-371.1	-322	8160.	-49.1	-272.1	-103.1	218.9	49.9
14:54:08	53648	9076	9306	8992	9422.6	-430.6	-390	9382.	-40.6	-346.6	-116.6	273.4	43.4
14:55:27	53727	10146	10406	10060	10574.1	-514.1	-450	10510.	-64.1	-428.1	-168.1	281.9	21.9
14:57:27	53847	12185	12356	12077	12756.0	-679.0	-580	12657.	-99.0	-571.0	-400.0	180.0	9.0
14:58:33	53913	13346	13506	13239	13990.5	-751.5	-650	13889.	-101.5	-644.5	-484.5	165.5	5.5
14:59:45	53985	14817	14956	14678	15566.6	-888.0	-740	15418.	-148.6	-749.6	-610.6	129.4	-9.6
15:01:44	54104	16264	16306	16095	17084.1	-989.1	-845	16940	-144.1	-820.1	-778.1	66.9	24.9
15:03:00	54180	17245	17356	17070	18089.9	-1019.9	-910	17980.	-109.9	-844.9	-733.9	176.1	65.1
15:04:05	54245	18174	18306	18008	19037.0	-1029.0	-970	18978.	-59.0	-863.0	-731.0	239.0	107.0
15:05:20	54320	19175	19306	19002	20105.2	-1103.2	-1040	20042.	-63.2	-930.2	-799.2	240.8	109.8
15:06:44	54404	20203	20306	20009	21103.6	-1094.6	-1105	2111.4	10.4	-900.6	-797.6	307.4	204.4
15:08:00	54480	21204	21306	21004	22202.7	-1198.7	-1170	22174.	-28.7	-998.7	-896.7	273.3	171.3
15:10:28	54628	22377	22456	22163	23377.6	-1214.6	-1240	23403.	25.4	-1000.6	-921.6	318.4	239.4
15:12:49	54769	23653	23806	23443	24798.3	-1355.3	-1325	24768	-30.3	-1145.3	-992.3	333.7	179.7

TABLE A-II.- Continued

<u>SGMT,</u> <u>hr:min:sec</u>	<u>SGMT,</u> <u>sec</u>	<u>DFI ALT,</u> <u>ft</u>	<u>OI ALT,</u> <u>ft</u>	<u>SCA ALT,</u> <u>ft</u>	<u>Kalman</u> <u>ALT, ft</u>	<u>SCA-</u> <u>Kalman,</u> <u>ft</u>	<u>Error</u> <u>in 62</u> <u>standard,</u> <u>ft</u>	<u>True</u> <u>SCA,</u> <u>ft</u>	<u>True SCA-</u> <u>Kalman ALT,</u> <u>ft</u>	<u>DFI ALT-</u> <u>Kalman,</u> <u>ft</u>	<u>OI ALT-</u> <u>Kalman,</u> <u>ft</u>	<u>Corrected</u> <u>OI-Kalman,</u> <u>ft</u>	<u>Corrected</u> <u>DFI-Kalman,</u> <u>ft</u>
15:16:47	55007	25070	25156	24844	26355.0	-1511.0	-1420	26264.	-91.0	-1285.0	-1199.0	221.0	135.0
15:19:08	55148	25618	25756	25397	26961.4	-1564.4	-1450	26847.	-114.4	-1343.4	-1205.4	244.6	106.6
15:21:00	55260	26146	26256	25921	27510.9	-1589.9	-1470	27391.	-119.9	-1364.9	-1254.9	215.1	105.1
15:22:01	55321	26186	26306	25963	27286.3	-1365.3	-1470	27433	104.7	-1100.3	-980.3	489.7	369.7
15:23:00	55380	26337	26456	26110	27680.4	-1570.4	-1475	27585.	-95.4	-1343.4	-1224.4	250.6	131.6
15:24:00	55440	26601	26706	26371	27962.5	-1591.5	-1485	27856.	-106.5	-1361.5	-1256.5	228.5	123.5
15:25:00	55500	26528	26656	26297	27878.0	-1581.0	-1485	27782.	-96.0	-1350.0	-1222.0	263.0	135.0
15:26:00	55560	26678	26706	26437	27986.7	-1549.7	-1492	27929	-57.7	-1308.7	-1280.7	211.3	183.3
15:27:00	55562	26883	26906	26645	28514.0	-1869.0	-1500	28145.	-369.0	-1631.0	-1608.0	-108.0	-131.0
15:28:05	55685	27318	27356	27082	28637.1	-1555.1	-1515	28597.	-40.1	-1319.1	-1281.1	233.9	195.9
15:29:18	55758	27701	27756	27457	29059.5	-1602.5	-1525	2898.2	-77.5	-1358.5	-1303.5	221.5	166.5
15:29:56	55796	27874	27906	27628	29232.3	-1604.3	-1540	29168.	-64.3	-1358.3	-1326.3	213.7	181.7
15:32:15	55935	28445	28506	28205	29902.2	-1697.2	-1560	29765.	-137.2	-1457.2	-1697.2	-137.2	102.8
15:33:58	56038	28793	28906	28560	30237.4	-1677.4	-1570	30130.	-107.4	-1444.4	-1331.4	238.6	125.6
15:34:48	56088	28596	28806	28400	30211.2	-1811.2	-1570	29970.	-241.2	-1615.2	-1405.2	164.8	-45.2
15:34:52	56092	28321	28456	28092	29972.3	-1880.3	-1555	29647.	-325.3	-1651.3	-1516.3	38.7	-96.3
15:34:56	56096	27973	27956	27717	29603.4	-1886.4	-1535	29252.	-351.4	-1630.4	-1647.4	-112.4	-68.4
15:35:02	56102	27356	27456	27090	28984.7	-1894.7	-1515	28605.	-379.7	-1628.7	-1528.7	-13.7	-113.7
15:35:12	56112	26308	26356	26015	27867.3	-1852.3	-1470	27485.	-382.3	-1559.3	-1511.3	-41.3	-89.3
15:35:18	56118	25700	25756	25397	27249.4	-1852.4	-1450	26847.	-402.4	-1549.4	-1493.4	-43.4	-99.4
15:35:52	56152	23187	23306	22927	24436.2	-1509.2	-1290	24217	-219.2	-1249.2	-1130.2	159.8	40.8
15:36:40	56200	20988	21106	20718	22275.0	-1557.0	-1150	21868.	-407.0	-1287.0	-1169.0	-19.0	-137.0
15:36:52	56212	19988	20106	19720	21210.7	-1490.7	-1070	20790.	-420.7	-1222.7	-1104.7	-34.7	-152.7
15:37:05	56225	18959	19106	18700	20124.2	-1424.2	-1015	19715	-409.2	-1165.2	-1018.2	-3.2	-150.2
15:37:45	56265	15439	15456	15162	16364.0	-1202.0	-780	15942.	-422.0	-925.0	-908.0	-128.0	145.0

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TABLE II.- Concluded

<u>SGMT,</u> <u>hr:min:sec</u>	<u>SGMT,</u> <u>sec</u>	<u>DFI ALT,</u> <u>ft</u>	<u>OI ALT,</u> <u>ft</u>	<u>SCA ALT,</u> <u>ft</u>	<u>Kalman</u> <u>ALT, ft</u>	<u>SCA-</u> <u>Kalman,</u> <u>ft</u>	<u>Error</u> <u>in 62</u> <u>standard,</u> <u>ft</u>	<u>True</u> <u>SCA,</u> <u>ft</u>	<u>True SCA-</u> <u>Kalman ALT,</u> <u>ft</u>	<u>DFI ALT-</u> <u>Kalman,</u> <u>ft</u>	<u>OI ALT-</u> <u>Kalman,</u> <u>ft</u>	<u>Corrected</u> <u>OI-Kalman,</u> <u>ft</u>	<u>Corrected</u> <u>DFI-Kalman,</u> <u>ft</u>
15:37:56	56276	14552	14606	14304	15352.4	-1048.4	-715	15019.	-33.4	-800.4	-746.4	-31.4	-85.4
15:38:04	56284	13971	14006	13721	14810.5	-1089.5	-665	14386.	-424.5	-839.54	-804.5	-139.5	-174.5
15:38:12	56292	13481	13506	13252	14261.1	-1009.1	-652	13904.	-357.1	-780.1	-755.1	-103.1	-128.1
15:38:50	56330	11034	11106	10812	11743.5	-931.5	-500	11512.	-431.5	-709.5	-637.5	-137.5	-209.5
15:39:30	56370	7318	7456	7066	7820.8	-754.8	-280	7346.	-474.8	-502.8	-364.8	-84.8	-222.8
15:39:39	56379	6426	6606	6172	6893.9	-721.9	-225	6397.	-496.9	-467.9	-287.9	-62.9	-242.9
15:39:48	56388	5554	5656	5311	5953.5	-642.5	-180	5491.	-462.5	-399.5	-297.5	-117.5	-219.5
15:40:00	56400	4540	4706	4300	4859.9	-559.9	-120	4420.	-439.9	-319.9	-153.9	-33.9	-199.9
15:40:24	56424	3082	2876	2939	3211.9	-272.9	--	--	--	-129.9	-335.9	--	--
15:40:40	56440	2954	3096	2857	3024.4	-167.4	--	--	--	-70.4	+71.6	--	--
15:40:55	56455	3106	3121	2986	3167.0	-181.0	--	--	--	-61.0	-46.0	--	--
15:41:10	56470	3397	3646	3294	3451.9	-157.9	--	--	--	-54.9	194.1	--	--
15:41:25	56485	3643	3656	3514	3699.9	-185.9	-70	3584.	-115.9	-56.9	-43.9	26.1	13.1
15:41:40	56500	3783	3806	3669	3834.4	-165.4	-85	3754.	-80.4	-51.4	-28.4	56.6	33.6
15:41:55	56515	3847	3956	3733	3975.1	-242.1	-85	3818.	-157.1	-128.1	-19.1	65.9	-43.1
15:42:10	56530	3789	3906	3684	3891.8	-207.8	-85	3769.	-122.8	-102.8	14.2	70.8	-17.8
15:42:40	56560	3889	4006	3786	3980.0	-194.0	-90	3876.	-104.0	-91.0	26.0	116.0	-1.0
15:43:30	56610	3907	3956	3791	4007.6	-216.6	-90	3881.	-126.6	-100.6	-51.6	35.4	-10.6
15:44:30	56670	3590	3711	3489	3684.9	-195.9	--	--	--	-94.9	26.1	--	--
15:46:00	56760	2719	2901	2636	2840.7	-204.7	--	--	--	-121.7	60.3	--	--
15:46:34	56794	2329	2471	2248	2454.5	-206.5	--	--	--	-125.5	16.5	--	--
15:46:59	56819	2188	2321	2134	2290.6	-156.6	--	--	--	-102.6	30.4	--	--
15:47:12	56832	2187	2301	2139	2288.9	-149.9	--	--	--	-101.9	12.1	--	--
15:47:45	56865	2182	2281	2155	2281.0	-126.0	--	--	--	-99.0	0.0	--	--
15:47:58	56878	2182	2296	2163	2281.3	-118.3	--	--	--	-99.3	14.7	--	--

TABLE A-III.- FREE FLIGHT 1

<u>SGMT,</u> <u>hr:min:sec</u>	<u>SGMT,</u> <u>sec</u>	<u>DFI ALT,</u> <u>ft</u>	<u>OI ALT,</u> <u>ft</u>	<u>SCA ALT,</u> <u>ft</u>	<u>Kalman</u> <u>ALT, ft</u>	<u>SCA-</u> <u>Kalman,</u> <u>ft</u>	<u>Error</u> <u>in 62</u> <u>standard,</u> <u>ft</u>	<u>True</u> <u>SCA,</u> <u>ft</u>	<u>True SCA-</u> <u>Kalman ALT,</u> <u>ft</u>	<u>DFI ALT-</u> <u>Kalman,</u> <u>ft</u>	<u>OI ALT-</u> <u>Kalman,</u> <u>ft</u>	<u>Corrected</u> <u>OI-Kalman,</u> <u>ft</u>	<u>Corrected</u> <u>DFI-Kalman,</u> <u>ft</u>
15:11:06	54666.	15122	15206	14989	15826.5	-837.5	-840	15829.	2.5	-704.5	-620.5	219.5	135.5
15:11:59	54719.	15894	15956	15752	16642.6	-890.6	-885	16637.	-5.6	-788.6	-689.6	198.4	136.4
15:12:59	54779.	16860	16906	16710	17659.5	-949.5	-940	17650.	-9.5	-799.5	-753.5	186.5	140.5
15:14:00	54840.	17700	17706	17535	18534.5	-999.5	-990	18525.	-9.5	-834.5	-828.5	161.5	155.5
15:15:13	54913.	18405	18356	18212	19240.7	1028.7	-1040	19252.	11.3	-832.7	-884.7	155.3	207.3
15:16:07	54967.	19136	19206	18963	20001.2	-1038.2	-1080	20043.	41.8	-865.2	-795.2	284.8	214.8
15:17:00	55020.	19844	19906	19666	20726.3	-1060.3	-1125	20791.	64.7	-882.3	-820.3	304.7	242.7
15:18:55	55135.	21290	21306	21094	22200.8	-1106.8	-1200	22294.	93.2	-910.8	-894.8	305.2	289.2
15:21:14	55274.	22712	22706	22501	23589.1	-1088.1	-1270	23771.	181.9	-877.1	-883.1	386.9	392.9
15:23:25	55405.	23597	23606	23381	24545.2	-1164.2	-1300	24681.	135.8	-948.2	-939.2	360.8	351.8
15:23:55	55435.	23849	23856	23637	24818.4	-1181.4	-1325	24962.	143.6	-969.4	-962.4	362.6	355.6
15:24:42	55482.	24205	24206	23981	25196.9	-1215.9	-1340	25321.	124.1	-991.9	-990.9	349.1	348.1
15:25:17	55517.	24474	24506	24252	25517.1	-1265.1	-1355	25607.	89.9	-1043.1	-1011.1	343.9	311.9
15:27:05	55625.	25146	25156	24919	26252.6	-1333.6	-1385	26304.	51.4	-1106.6	-1096.6	288.4	278.4
15:28:01	55681.	25383	25356	25754	26521.1	-1367.1	-1425	26579.	57.9	-1138.1	-1165.1	259.9	286.9
15:31:00	55860.	26103	26106	25869	27287.8	-1418.8	-1430	27299.	11.2	-1184.8	-1181.8	248.2	245.2
15:31:38	55898.	26195	26256	25973	27390.3	-1417.3	-1435	27408.	17.7	-1195.3	-1134.3	300.7	239.7
15:32:57	55977.	26313	26306	26076	27503.5	-1427.5	-1442	27518.	14.5	-1190.5	-1197.5	244.5	251.5
15:35:20	56120.	26460	26456	26233	27645.5	-1412.5	-1450	27683.	37.5	-1185.5	-1189.5	260.5	264.5
15:37:00	56220.	26478	26456	26239	27638.4	-1399.4	-1450	27689.	50.6	-1160.4	-1182.4	267.6	289.6
15:38:29	56309.	26668	26606	26424	27804.4	-1380.4	-1460	27884.	79.6	-1136.4	-1198.4	263.6	323.6
15:39:09	56347.	26925	26856	26693	28035.5	-1342.5	-1475	28168.	132.5	-1110.5	-1179.5	295.5	364.5
15:40:05	56405.	27285	27206	27017	28339.8	-1372.8	-1490	28507.	117.2	-1104.8	-1183.8	306.2	385.2
15:41:03	56463.	27606	27556	27363	28761.8	-1398.8	-1505	28868.	106.2	-1155.8	-1705.8	299.2	349.2
15:42:07	56527.	27783	27706	27529	28890.4	-1361.4	-1515	29044.	153.6	-1107.4	-1184.4	530.6	407.6

TABLE A-III.- Continued

<u>SGMT,</u> <u>hr:min:sec</u>	<u>SGMT,</u> <u>sec</u>	<u>DFI ALT,</u> <u>ft</u>	<u>OI ALT,</u> <u>ft</u>	<u>SCA ALT,</u> <u>ft</u>	<u>Kalman</u> <u>ALT, ft</u>	<u>SCA-</u> <u>Kalman,</u> <u>ft</u>	<u>Error</u> <u>in 62</u> <u>standard,</u> <u>ft</u>	<u>True</u> <u>SCA,</u> <u>ft</u>	<u>True SCA-</u> <u>Kalman ALT,</u> <u>ft</u>	<u>DFI ALT-</u> <u>Kalman,</u> <u>ft</u>	<u>OI ALT-</u> <u>Kalman,</u> <u>ft</u>	<u>Corrected</u> <u>OI-Kalman,</u> <u>ft</u>	<u>Corrected</u> <u>DFI-Kalman,</u> <u>ft</u>
15:43:26	56606.	28049	28056	27809	29296.8	-1487.8	-1540	29349.	52.2	-1247.8	-1240.8	299.2	292.2
15:45:11	56711.	28392	28406	28154	29704.1	-1550.1	-1550	29704.	- .1	-1312.1	-1298.1	251.9	237.9
15:45:55	56744.	28580	28506	28318	29830.4	-1512.4	-1555	29873.	42.6	-1250.4	-1324.4	230.6	304.6
15:46:11	56771.	28673	28656	28426	30039.4	-1613.4	-1562	29988.	-51.4	-1366.4	-1383.4	178.6	195.6
15:47:04	56824.	28872	28856	28632	30233.7	-1601.7	-1570	30202.	-31.7	-1361.7	-1377.7	192.3	208.3
15:47:31	56851.	28881	28906	28649	30254.7	-1605.7	-1570	30219.	-35.7	-1373.7	-1348.7	221.3	196.3
15:48:44	56924.	24946	24956	23091	26353.7	-3262.7	-1300	24391.	-1962.7	-1407.7	-1397.7	-97.7	-107.7
15:48:54	56934.	24139	24156	22408	25516.6	-3108.6	-1265	23673.	-1843.6	-1377.6	-1360.6	-95.6	-112.6
15:49:08	56948.	22465	22406	21836	23738.1	-1902.1	-1240	23076.	-662.1	-1273.1	-1332.1	-92.1	-33.1
15:49:21	56961.	22299	22306	21288	23556.8	-2268.8	-1210	22498.	-1058.8	-1257.8	-1250.8	-40.8	-47.8
15:49:30	56970.	22379	22406	20978	23626.6	-2648.6	-1200	22178.	-1448.6	-1247.6	-1220.6	-20.6	-47.6
15:49:42	56982.	22464	22456	20350	23699.6	-3349.6	-1160	21510.	-2189.6	-1235.6	-1243.6	-83.6	-75.6
15:49:49	56989.	22371	22356	19892	23600.1	-3708.2	-1135	21027.	-2573.1	-1229.1	-1244.1	-109.1	-94.1
15:49:59	56999.	21740	21706	19219	22951.4	-3732.4	-1160	20319.	-2632.4	-1211.4	-1245.4	-145.4	-111.4
15:50:16	57016.	20098	20156	18236	21243.3	-3003.3	-1040	19276.	-1957.3	-1145.3	-1087.3	-47.3	-105.3
15:50:27	57027.	18970	18956	17361	20035.1	-2674.1	-980	18341.	-1694.1	-1065.1	-1079.1	-99.1	-85.1
15:50:33	57033.	18413	18406	16807	19451.1	-2644.1	-950	17757.	-1694.1	-1038.1	-1045.1	-95.1	-88.1
15:50:42	57042.	17546	17506	15975	18557.6	-2582.6	-895	16870.	-1687.6	-1006.6	-1046.6	-151.6	-111.6
15:50:51	57051.	16706	16656	15208	17666.6	-2458.6	-850	16058.	1608.6	-960.6	-1010.6	-160.6	-110.6
15:50:55	57055	16330	16306	14886	17274.0	-2388.0	-835	15721.	-1553.0	-944.0	-968.0	-133.0	-109.0
15:51:06	57066	15406	15406	14097	16308.2	-2211.2	-790	14887.	-1421.0	-902.2	-902.2	-112.2	-112.2
15:51:12	57072	14937	14906	13723	15807.4	-2084.4	-765	14488.	-1319.4	-870.4	-901.4	-136.4	-105.4
15:51:17	57077	14512	14456	13388	15343.2	-1955.2	-740	14128.	-1215.2	-831.2	-887.2	-147.2	-91.2
15:51:22	57082	14099	14006	13018	14916.0	-1898.0	-720	13728	-1178.0	-817.70	-910.0	-190.0	-97.0
15:51:28	57088	13582	13506	12527	14372.9	-1845.9	-685	13212	-1160.9	-790.9	-866.9	-181.9	-105.9

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TABLE A-III.- Concluded

SGMT, hr:min:sec	SGMT, sec	DFI ALT, ft	OI ALT, ft	SCA ALT, ft	Kalman ALT, ft	SCA- Kalman, ft	Error in 62 standard, ft	True SCA, ft	True SCA- Kalman ALT, ft	DFI ALT- Kalman, ft	OI ALT- Kalman, ft	Corrected OI-Kalman, ft	Corrected DFI-Kalman, ft
15:51:34	57094.	13009	12956	11992	13770.6	-1778.6	-655	12647.	-1123.6	-761.6	-814.6	-159.6	-106.6
15:51:40	57100.	12320	12306	11424	13052.0	-1628.0	-620	12044.	-1008.0	-732.0	-746.0	-126.0	-112.0
15:51:45	57105.	11750	11756	10959	12439.0	-1500.0	-598	11557.	-902.0	-689.0	-683.0	-85.0	-91.0
15:51:49	57109.	11305	11306	10604	11969.2	-1365.2	-570	11174.	-795.2	-664.2	-663.2	-93.2	-94.2
15:51:52	57112.	10966	11006	10404	11752.4	-1348.4	-560	10964.	-788.4	-786.4	-746.4	-186.4	-226.4
15:51:59	57119.	10212	10256	9838	10808.6	-970.6	-520	10358.	-450.6	-596.6	-552.6	-32.6	-76.1
15:52:11	57131.	5861	8906	9040	9380.9	-370.9	-465	9505.	124.1	-519.9	-474.9	-9.9	-54.9
15:52:17	57137.	8171	8206	8650	8645.2	4.8	-440	9090.	444.8	-474.2	-439.2	.8	-34.2
15:52:22	57142.	7659	--	8206	8096.7	109.3	-420	8626.	529.3	-437.7	--	--	-17.7
15:52:28	57148.	7052	7056	7711	7441.1	269.9	-390	8101.	659.9	-389.1	-385.1	4.9	.9
15:52:33	57153.	6516	6556	7306	6861.1	444.9	-355	7661.	799.9	-345.1	-305.1	49.9	9.9
15:52:38	57158.	5946	6006	6915	6252.5	-662.5	-330	7245.	992.5	-306.5	-246.5	83.5	23.5
15:52:44	57164.	5260	5356	6490	5515.5	979.5	-300	6790.	1274.5	-255.5	-159.5	140.5	44.5
15:52:51	57171.	4431	4556	5990	4621.5	1368.5	-260	6250	1628.5	-190.5	-65.5	194.5	69.5
15:52:58	57178.	3668	3696	5500	3810.1	1689.9	-225	5725	1914.9	-142.1	-114.1	110.9	82.9
15:53:05	57185.	3057	3121	5038	3140.7	1897.3	-195	5233.	2092.3	-83.7	-19.7	175.3	111.3
15:53:11	57191	2679	2681	4712	2726.8	1985.2	-175	4887.	2160.2	-47.8	-45.8	129.2	127.2
15:53:16	57196	2445	2436	4712	2481.7	2230.3	-175	4887.	2405.3	-36.7	-45.7	129.3	138.3
15:53:21	57201	2324	2336	4712	2354.3	2357.7	-175	4887.	2532.7	-30.3	-18.3	156.7	144.7
15:53:26	57206.	2263	2391	4127	2283.5	1843.5	-125	4552.	2268.7	-20.5	107.5	232.5	104.5
15:53:32	57212	2237	2356	4127	2273.0	1854.0	-125	4552.	2279.0	-36.0	83.0	208.0	89.0
15:53:40	57220	2221	2291	3780	2247.8	1532.2	-100	3880	1632.2	-26.8	43.2	143.2	73.2
15:53:41	57221.	2221	2296	3780	2262.2	1517.8	-100	3880	1617.8	-41.2	33.8	133.8	58.8
15:53:44	57224.	2220	2296	3780	2223.8	1556.2	-100	3880	1656.2	-3.8	72.2	172.2	96.2
15:53:50	57230.	2223	2296	3780	2230.8	1549.2	-100	3880	1649.2	-7.8	65.2	165.2	92.2

TABLE A-IV.- THEODOLITE DATA FOR FREE FLIGHT 1

<u>Time, sec</u>	<u>Hr:min:sec</u>	<u>Z Kalman, ft</u>	<u>Z Theodolite, ft</u>	<u>Theodolite- Kalman, ft</u>
56870	15:47:50	27759	27797	38
56880	15:48:00	26836	26890	54
56890	15:48:10	25817	25859	42
56900	15:48:20	24855	24885	30
56910	15:48:30	23838	23913	75
56920	15:48:40	24062	24088	26
56930	15:48:50	23725	23750	25
56940	15:49:00	22395	22426	31
56950	15:49:10	21349	21399	50
56960	15:49:20	21276	21312	36
56970	15:49:30	21341	21382	41
56980	15:49:40	21425	21471	46
56990	15:49:50	21285	21318	33
57000	15:50:00	20531	20567	36
57010	15:50:10	19472	19513	41
57020	15:50:20	18480	18517	37
57030	15:50:30	17414	17458	44
57040	15:50:40	16408	16453	45
57050	15:50:50	15427	15471	44
57060	15:51:00	14466	14503	37
57070	15:51:10	13652	13694	42
57080	15:51:20	12765	12805	40
57090	15:51:30	11874	11908	34
57100	15:51:40	10756	10781	25
57110	15:51:50	9571	9590	19
57120	15:52:00	8426	8439	13
57130	15:52:10	7248	7245	-3
57140	15:52:20	6062	6056	-6
57150	15:52:30	4971	4964	-7
57160	15:52:40	3774	3769	-5
57170	15:52:50	2518	2513	-5
57180	15:53:00	1367	1371	4
57190	15:53:10	566	574	8
57200	15:53:20	146	158	12
57210	15:53:30	47	60	13
57220	15:53:40	33	31	-2
57230	15:53:50	8	23	15

TABLE A-V.- RADAR ALTIMETER DATA VS KALMAN RADAR

FREE FLIGHT 1 (UPPER C-BAND ANTENNA Z COMPONENT)

<u>SGMT,</u> <u>sec</u>	<u>RA</u> <u>ALT,</u> <u>ft</u>	<u>Kalman</u> <u>ALT,</u> <u>ft</u>	<u>RA-</u> <u>Kalman,</u> <u>ft</u>	<u>Corrected</u> <u>RA-</u> <u>Kalman, ft</u>	<u>SGMT,</u> <u>sec</u>	<u>RA</u> <u>ALT,</u> <u>ft</u>	<u>Kalman</u> <u>ALT,</u> <u>ft</u>	<u>RA-</u> <u>Kalman,</u> <u>ft</u>	<u>Corrected</u> <u>RA-</u> <u>Kalman, ft</u>
57149	5113	5085	28	43	57186	851	834	17	32
57150	4993	4971	22	37	57187	778	755	23	38
57151	4880	4856	24	39	57188	707	684	23	38
57152	4761	4740	21	36	57189	642	625	17	32
57153	4646	4622	24	39	57190	579	566	13	28
57154	4521	4503	18	23	57191	524	504	20	35
57155	4404	4381	23	38	57192	467	446	21	36
57156	4280	4260	20	35	57193	413	401	12	27
57157	4162	4137	25	40	57194	356	349	7	22
57158	4035	4015	20	35	57195	307	295	12	27
57159	3917	3896	21	36	57196	264	251	13	28
57160	3794	3774	20	35	57197	228	215	13	28
57161	3674	3651	23	38	57298	199	178	11	26
57162	3551	3528	23	38	57199	175	154	21	36
57163	3434	3406	28	43	57200	152	146	6	21
57164	3399	3282	17	32	57201	129	130	-1	14
57165	3175	3157	18	33	57202	113	115	-2	13
57166	3044	3030	14	29	57203	97	106	-9	6
57167	2919	2900	19	34	57204	85	96	-11	4
57168	2788	2771	17	32	57205	76	71	5	20
57169	2662	2643	19	34	57206	69	62	7	22
57170	2530	2518	12	27	57207	62	59	3	18
57171	2407	2390	17	32	57208	61	55	6	21
57172	2278	2260	18	33	57209	57	51	6	21
57173	2156	2139	17	32	57210	52	47	5	20
57174	2036	2021	15	30	57211	39	46	-7	8
57175	1923	1909	14	29	57214	37	33	4	19
57176	1808	1799	9	24	57214	32	37	-5	10
57177	1707	1685	22	37	57215	33	46	-13	2
57178	1589	1577	12	27	57216	25	81	-56	-41
57179	1487	1475	12	27	57218	24	2	22	37
57180	1385	1367	18	33					
57181	1289	1278	11	26					
57182	1193	1183	10	25					
57183	1101	1083	18	33					
57184	1016	999	17	32					
57185	931	916	15	30					

TABLE A-VI.- MSBLS VS KALMAN ALTITUDE FOR FREE FLIGHT 1

<u>Kalman ALT, ft</u>	<u>MSBLS ALT, ft</u>	<u>MSBLS - Kalman, ft</u>
19325	19560	+235
19002	19189	+187
18571	18722	+151
17495	17556	61
17107	17200	93
16725	16787	61
16339	16339	0
15879	15924	46
11944	11986	41
11681	11664	-17
11407	11368	-39
11128	11079	-48
10846	10845	-1
10576	10614	38
10324	10308	-15
10088	10088	0
9841	9811	-30
9603	9591	-12
9363	9352	-11
9119	9106	-13
8860	8858	-2
8586	8591	5
8301	8268	-32
8006	7961	-44
7682	7641	-41
7354	7345	-9
7047	7024	-23
6724	6701	-23
6385	6346	-38
6003	6015	12
5616	5617	1
4832	4826	-5
4465	4458	-7
4103	4087	-16
3726	3713	-13
3346	3342	-4
3303	2985	-17
2680	2672	-8
2359	2359	0
2027	2033	5
1793	1772	-20
1521	1535	14
1311	1273	-38
1040	1067	26
834	812	-21
697	743	46

TABLE A-VI.- Concluded

<u>Kalman ALT, ft</u>	<u>MSBLS ALT, ft</u>	<u>MSBLS - Kalman, ft</u>
650	525	-125
610	439	-171
496	456	-39
498	431	-67
541	419	-121
625	576	-48
763	595	-168

TABLE A-VII.- FREE FLIGHT 2

<u>Time,</u> <u>hr:min:sec</u>	<u>DPI,</u> <u>ft</u>	<u>OI,</u> <u>ft</u>	<u>SCA,</u> <u>ft</u>	<u>Kalman,</u> <u>ft</u>	<u>DPI-Kalman,</u> <u>ft</u>	<u>OI-Kalman,</u> <u>ft</u>	<u>SCA-Kalman,</u> <u>ft</u>	<u>Theodolite</u> <u>(Z), ft</u>	<u>Kalman</u> <u>(Z), ft</u>	<u>Theodolite</u> <u>Kalman (Z), ft</u>
15:00:51	2309	2401	2241	2294	15	107	-53			
54051										
15:01:38	3015	3161	2938	2978	37	183	-40			
54098										
15:02:23	4065	4306	4005	4059	6	247	-54			
54143										
15:02:59	5051	5206	4974	5090	39	+116	-116			
54179										
15:03:31	6070	6256	5995	6157	-87	99	-162			
54211										
15:04:14	7075	7256	6992	7209	-134	47	-217			
54254										
15:04:56	8148	8306	8074	8340	-192	-34	-266			
54296										
15:05:47	9355	9506	9265	9599	-244	-93	-334			
54347										
15:06:16	10084	10256	9994	10352	-268	-96	-358			
54376										
15:08:24	13092	13406	12986	13510	-418	-104	-524			
54504										
15:09:31	14104	14406	13999	14642	-538	-236	-643			
54573										
15:10:22	15207	15406	15079	15724	-517	-318	-645			
54622										
15:11:23	16203	16356	16086	16753	-550	-397	-667			
54683										
15:12:19	17058	17206	16917	17693	-635	-487	-776			
54739										
15:13:45	18169	18306	18002	18832	-663	-526	-830			
54825										
15:15:02	19369	19406	19172	20088	-719	-682	-916			
54902										
15:18:01	21406	21556	21215	22209	-803	-653	-994			
55081										
15:25:57	25314	25406	25088	26196	-882	-790	-1108			
55557										
15:28:26	25858	25956	25636	no radar	--	--	--			
55706										
15:31:41	26398	26406	26168	17293?	--	--	--			
55901										
15:34:19	26697	26756	26464	27704	-1007	-948	-1240			
56059										
15:35:10	26731	26956	26493	27734	-1003	-778	-1241			
56110										
15:37:30	26755	26856	26522	27764	-1009	-908	-1242			
56250										
15:40:45	27620	27606	27369	28629	-1009	-1023	-1260			
56445										
15:41:37	27807	27806	27576	28829	-1022	-1023	-1253			
56497										
15:42:41	27916	27956	27670	28953	-1037	-997	-1285			
56561										

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TABLE A-VII.- Continued

<u>Time, hr:min:sec</u>	<u>DFI, ft</u>	<u>OI, ft</u>	<u>SCA, ft</u>	<u>Kalman, ft</u>	<u>DFI-Kalman, ft</u>	<u>OI-Kalman, ft</u>	<u>SCA-Kalman, ft</u>	<u>Theodolite (Z), ft</u>	<u>Kalman (Z), ft</u>	<u>Theodolite Kalman (Z), ft</u>
15:43:31 56619	28206	28306	27974	29243	-1037	-937	-1269			
15:44:30 56670	28372	28406	28137	29488	-1116	-1082	-1351			
15:45:30 56730	28587	28656	28346	29707	-1120	-1051	-1361			
15:46:47 56807	28975	29006	28732	30112	-1137	-1106	-1380			
15:48:00 56880	29245	29306	29004	30392	-1147	-1086	-1388			
15:49:01 56941	27838	27656	27562	28863	-1025	-1207	-1301			
15:49:10 56950	26980	26806	26701	27982	-1002	-1176	-1281			
15:49:15 56955	26536	26406	26249	27520	-984	-1114	-1271			
15:49:20 56960	26081	25856	25781	27059	-978	-1203	-1278			
15:49:26 56966	25521	25306	25182	26444	-923	-1138	-1262	24211	24159	52
15:49:30 56970	24992	24806	24856	26123	-1131	-1317	-1267	23887.9	23832	56
15:49:34 56974	24739	24656		25728	-989	-1072		23639.8	23431	209
15:49:42 56982	23807	23256		24852	-1045	-1596		22593.4	22540	53
15:49:48 56988	22642	22306		23637	-995	-1331		21374.6	21312	63
15:49:55 56995	21558	21006		22307	-749	-1301		20033.0	19967	66
15:50:00 57000	20655	20506		21632	-977	-1126		19352.1	19279	73
15:50:06 57006	20156	19956		2111	-955	-1155		18816.9	18742	75
15:50:10 57010	19815	19606		20734	-919	-1128		18431.2	18355	76
15:50:15 57015	19298	19106		20182	-884	-1076		17864.6	17789	76
15:50:21 57021	18652	18356		19495	-843	-1139		17163.5	17085	78
15:50:25 57025	18152	17856		18956	-904	-1100		16617.0	16534	83
15:50:31 57031	17309	17056		18068	-759	-1012		15723.6	15628	96
15:50:34 57034	16821	16606		17691	-870	-1085		15328.7	15242	87
15:50:39 57039	16427	16256		17171	-744	-915		14816.3	14706	110
15:50:42 57043	16190	16256		16947	-757	-891		14582.7	14469	111
15:50:43 57044	16153	16056		16917	-764	-861		14545.2	14436	109

TABLE A-VII.- Concluded

<u>Time, hr:min:sec</u>	<u>DFI, ft</u>	<u>OI, ft</u>	<u>SCA, ft</u>	<u>Kalman, ft</u>	<u>DFI-Kalman, ft</u>	<u>OI-Kalman, ft</u>	<u>SCA-Kalman, ft</u>	<u>Theodolite (Z), ft</u>	<u>Kalman (Z), ft</u>	<u>Theodolite Kalman (Z), ft</u>
15:51:07 57067	16602	16606		17358	-756	-752		14968.1	14858	104
15:51:13 57073	16426	16356		17144	-718	-788		14754.8	14654	101
15:51:24 57084	15850	15756		16511	-661	-755		14142.4	14038	104
15:51:35 57095	15109	15006		15739	-6230	-733		13381.2	13283	98
15:51:46 57106	14465	14506		15089	-624	-583		12743.8	12649	95
15:52:00 57119	13796	13706								
15:52:29 57149	11693	11506		12111	-418	-605		9813.7	9732	92
15:52:36 57156	10983	10806		11386	-403	-580		9090.7	9019	72
15:52:43 57163	10426	10306		10800	-374	-494		8520.6	8446	75
15:52:49 57169	10024	9906		10401	-377	-495		8107.7	8056	52
15:53:03 57183	9102	8956		9422	-320	-466		7145.9	7098	48
15:53:17 57197	8111	7906		8372	-261	-466		6106.2	6067	39
15:53:23 57203	7603	7406		7830	-227	-424		5572.2	5534	38
15:53:34 57214	6577	6456		6786	-209	-330		5572.2	5534	38
15:53:47 57227	5440	5256		5554	-114	-298		4534.1	4502	32
15:53:57 57237	4474	4406		4520	-46	-114		3312.0	3284	28
15:54:13 57253	2924	2726		2912	12	-186		2281.2	2259	22
15:54:28 57268	2337	2331		2877	-540	-546		683.6	665	19
15:54:48 57288	2192	2296		2246	-54	+50		146.5	125	21
15:55:03 57303	2179	2276		2230	-51	+46		17.3	5	12

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TABLE A-VIII.- UPPER AIR DATA FOR FREE FLIGHT 2

<u>62 standard altitude, ft</u>	<u>True altitude, ft</u>	<u>62 standard minus true, ft</u>
2316.4	2375.	-58.6
2923.4	3000.	-76.6
3883.6	4000.	-116.4
4840.3	5000.	159.7
5793.9	6000.	-206.1
6742.1	7000.	-257.9
7688.2	8000.	-311.8
8635.1	9000.	-364.9
9583.0	10000.	-417.0
10531.9	11000.	-468.1
11479.1	12000.	-520.9
12425.2	13000.	-574.8
13370.1	14000.	-629.9
14315.1	15000.	-684.9
15260.5	16000.	-739.5
16207.2	17000.	-792.8
17155.4	18000.	-844.6
18105.2	19000.	-894.8
19057.0	20000.	-943.0
20007.6	21000.	-992.4
20958.3	22000.	-1041.7
21910.7	23000.	-1089.3
22867.1	24000.	-1132.9
23827.8	25000.	-1172.2
24790.2	26000.	-1209.8
25753.8	27000.	-1246.2
26718.8	28000.	-1281.2
27682.1	29000.	-1317.9
28645.6	30000.	-1354.4
29612.5	31000.	-1387.5
30582.9	32000.	-1417.1
31554.6	33000.	-1445.4
32527.7	34000.	-1472.3

TABLE A-IX.- FREE FLIGHT 3

<u>Time, hr:min:sec</u>	<u>DFI, ft</u>	<u>OI, ft</u>	<u>SCA, ft</u>	<u>Kalman, ft</u>	<u>DFI-Kalman, ft</u>	<u>OI-Kalman, ft</u>	<u>SCA-Kalman, ft</u>	<u>Theodolite (Z), ft</u>	<u>Kalman (Z), ft</u>	<u>Theodolite Kalman (Z), ft</u>
15:03:52	6406	6456	6319	6343	63	113	-24			
54232										
15:04:58	8565	8606	8486	8586	-21	20	-100			
54298										
15:06:11	10449	10556	10365	9094	1355	1462	1271			
54311										
15:07:51	12395	12506	12308	12607	-212	-101	-299			
54471										
15:08:36	13243	13256	13142	13508	-265	-252	-366			
54516										
15:09:40	14056	14106	13946	14385	-329	-279	-439			
54580										
15:10:36	15196	15206	15081	15583	-387	-377	-502			
54636										
15:11:12	15856	15856	15725	16262	-406	-406	-537			
54672										
15:12:36	16805	16706	16646	17260	-455	-554	-614			
54756										
15:14:06	18058	18056	17905	18603	-545	-547	-698			
54846										
15:15:48	19377	19356	19213	19916	-539	-560	-703			
54948										
15:16:55	20231	20206	20068	20787	-556	-581	-719			
55015										
15:17:55	20845	20806	20671	21394	-549	-588	-723			
55075										
15:18:13	21082	21006	20903	21670	-588	-664	-767			
55093										
15:19:19	21613	21556	21430	22132	-519	-576	-702			
55159										
15:22:09	21357	23106	22955	23840	-683	-734	-885			
55329										
15:25:13	24326	24256	24135	25140	-814	-884	-1005			
55513										
15:26:20	24872	24806	24664	25639	-767	-833	-975			
55580										
15:27:53	25314	25256	25114	26128	-814	-872	-1014			
55673										
15:29:19	25637	25556	25440	26474	-837	-918	-1034			
55759										
15:31:05	25993	25956	25796	26860	-867	-904	-1064			
55865										
15:32:19	26363	26306	26160	27243	-880	-937	-1083			
55939										
15:33:21	26366	26356	26160	27239	-873	-883	-1079			
56001										
15:35:26	26548	26456	26342	27408	-860	-952	-1066			
56126										
15:36:00	26814	26706	26589	27700	-886	-994	-1111			
56160										
15:37:00	26987	26906	26774	27887	-900	-981	-1113			
56220										

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TABLE A-IX.- Concluded

<u>Time, hr:min:sec</u>	<u>DFI, ft</u>	<u>OI, ft</u>	<u>SCA, ft</u>	<u>Kalman, ft</u>	<u>DFI-Kalman, ft</u>	<u>OI-Kalman, ft</u>	<u>SCA-Kalman, ft</u>	<u>Theodolite (Z), ft</u>	<u>Kalman (Z), ft</u>	<u>Theodolite Kalman (Z), ft</u>
15:38:00	27018	26956	26814	27933	-915	-977	-1119			
56280										
15:39:00	27024	26956	26796	27993	-969	-1037	-1197			
56340										
15:40:10	27378	27256	27142	28361	-983	-1105	-1219			
56410										
15:41:44	27869	27856	27664	28909	-1040	-1053	-1245			
56504										
15:42:37	28154	28106	27946	29198	-1044	-1092	-1252			
56557										
15:43:00	28277	28256	28061	29321	-1044	-1065	-1260			
56580										
15:44:58	28656	28606	28472	29739	-1083	-1133	-1267			
56698										
15:45:32	26417	26156	26218	27379	-962	-1223	-1161	25166.4	25139	26
56732										
15:46:01	23555	23006		24540	-985	-1534		22314.8	22276	29
56761										
15:46:29	19608	19306		20432	-824	-1126		18161.1	18130	31
56789										
15:47:01	16550	16156		17195	-645	-1039		14863.7	14829	35
56821										
15:47:27	15249	15106		15789	-540	-683		13427.8	13382	47
56847										
15:48:04	14159	14006		14620	-461	-614		12293.2	12256	37
56884										
15:48:32	12195	11956		12542	-347	-586		10242.3	10210	32
56912										
15:49:03	10642	10506		10928	-286	-422		8659.7	8633	33
56943										
15:49:35	8020	7806	8142	8177	-157	-371	-35	5915.9	5914	2
56975										
15:50:01	5718	5456	5727	5777	-59	-121	-50	3535.0	3535	0
57001										
15:50:31	3203	3006	3153	3174	29	-168	-21	951.7	948	4
57031										
15:51:10	2278	2271	2247	2246	32	25	1	28.6	25	4
57070										
15:50:56	2313	2306	2263	2258	55	48	5	48.5	37	12
57056										

TABLE A-X.- UPPER AIR DATA FOR FREE FLIGHT 3

<u>True altitude, ft</u>	<u>62 standard altitude, ft</u>	<u>62 standard minus true, ft</u>
2375	2407	-32
3000	3014	-14
4000	3976	-24
5000	4934	-66
6000	5890	-110
7000	6848	-152
8000	7806	-194
9000	8758	-242
10000	9705	-295
11000	10651	-349
12000	11597	-403
13000	12541	-459
14000	13485	-515
15000	14423	-577
16000	15372	-628
17000	16316	-684
18000	17261	-739
19000	18217	-783
20000	19186	-814
21000	21183	--
22000	21051	-949
23000	22000	-1000
24000	22949	-1051
25000	23900	-1100
26000	24853	-1147
27000	25802	-1198
28000	26754	-1246
29000	27707	-1293
30000	28655	-1345
31000	29598	-1402
32000	30541	-1459
33000	31488	-1512
34000	32436	-1564
35000	33388	-1612

TABLE A-XI.- ALTITUDE DATA FOR FREE FLIGHT 4

<u>SGMT,</u> <u>hr:min:sec</u>	<u>SGMT,</u> <u>sec</u>	<u>DFI,</u> <u>ft</u>	<u>OI,</u> <u>ft</u>	<u>SCA,</u> <u>ft</u>	<u>Kalman,</u> <u>ft</u>	<u>DFI minus</u> <u>Kalman, ft</u>	<u>OI minus</u> <u>Kalman, ft</u>	<u>SCA minus</u> <u>Kalman, ft</u>	<u>Theodolite</u> <u>(Z), ft</u>	<u>Kalman</u> <u>(Z), ft</u>	<u>Theodolite-</u> <u>Kalman, ft</u>
14:45:00	53100	2128	2306	2101	2301	-173	+ 5	-200			
14:45:33	53133	2120	2296	2084	2291	-171	+ 5	-207			
14:46:08	53168	2312	2506	2233	2443	-131	63	-210			
14:46:20	53180	2544	2731	2467	2681	-137	50	-214			
14:48:11	53291	4692	4906	4609	4848	-156	58	-239			
14:51:00	53460	6869	7106	6779	7059	-190	47	-280			
14:52:07	53527	7615	7806	7516	7816	-201	- 10	-300			
14:52:59	53579	8102	8306	8009	8350	-248	- 44	-341			
14:56:12	53772	9392	9606	9278	9598	-206	8	-328			
15:05:05	54305	14704	14856	14559	14715	-11	-141	-156			
15:09:42	54582	16776	17006	16632	17221	-445	-215	-589			
15:10:13	54613	17077	17306	16932	17479	-402	-173	-547			
15:13:48	54828	18835	19056	18666	19400	-565	-344	-734			
15:16:41	55001	19415	19656	19293	20107	-692	-451	-814			
15:16:52	55012	19258	19456	19131	19950	-692	-494	-819			
15:16:36	54996	19199	19406	19069	20181	-982	-775	-1112			
15:17:34	55054	18551	18756	18456	19251	-700	-495	-795			
15:17:42	55062	18265	18456	18167	18954	-689	-498	-787			
15:18:04	55084	17766	18006	17662	18445	-679	-439	-783			
15:18:59	55139	14540	14706	14463	15130	-590	-424	-666			
15:19:11	55151	13919	14056	13799	14470	-551	-414	-671			
15:19:55	55195	14405	14556	14264	14946	-541	-390	-682			
15:20:58	55258	14925	15056	14781	15475	-550	-419	-694			
15:23:02	55382	15783	16006	15655	16350	-567	-344	-695			
15:25:42	55542	17012	17256	16877	17546	-534	-290	-669			
15:27:15	55635	17540	17806	17430	18133	-593	-327	-703			
15:28:55	55735	18185	18406	18026	18731	-546	-325	-705			
15:29:42	55782	18601	18806	18454	19110	-509	-304	-656			
15:31:05	55865	19108	19306	18955	19582	-474	-276	-627			
15:32:28	55948	19474	19706	19324	19758	-284	-52	-434			
15:34:47	56087	20581	20756	20399	21002	-421	-246	-603			
15:37:42	56262	21796	21956	21609	22324	-528	-368	-715			
15:38:36	56316	22124	22306	21940	22638	-514	-332	-698			
15:41:33	56493	23029	23206	22845	23744	-715	-538	-899			
15:44:59	56699	23787	24006	23539	24570	-783	-564	-1031			
15:49:24	56964	24433	24606	24255	25313	-880	-707	-1058			
15:50:00	57000	22749	22856	22563	23601	-852	-745	-1038			
15:50:12	57012	21685	21706	21464	22479	-794	-773	-1015	20197.8	20141	57
15:50:19	57019	21140	21256		22075	-935	-819		19806.9	19750	57
15:50:26	57026	21422	21656		22404	-982	-748		20129.7	20089	41
15:50:34	57034	21459	21556		22434	-975	-878		20170.3	20129	41
15:50:41	57041	20977	21106		21923	-946	-817		19679.3	19626	53
15:50:48	57048	20445	20406		21379	-934	-973		19136.3	19091	45
15:51:03	57063	18991	19106		19881	-890	-775		17635.2	17607	28
15:51:10	57072	18759	18906		19610	-861	-704		17356.9	17343	13
15:51:22	57082	17631	16906		17856	-825	-950		15609.9	15598	12
15:51:26	57086	16049	15956		16822	-773	-866		14579.3	14566	13
15:51:30	57090	15674	14906		15824	-750	-918		13585.9	13573	13
15:51:35	57093	14630	14556		15150	-520	-594		12910.5	12901	9
15:51:43	57103	12239	12006		12900	-661	-894		10662.4	10659	3
15:51:48	57108	11126	11006		11719	-593	-713		9485.1	9481	4
15:51:53	57113	9927	9806		10484	-557	-678		8253.0	8250	3

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TABLE A-XI.- Concluded

<u>SQMT,</u> <u>hr:min:sec</u>	<u>SQMT,</u> <u>sec</u>	<u>DFI,</u> <u>ft</u>	<u>OI,</u> <u>ft</u>	<u>SCA,</u> <u>ft</u>	<u>Kalman,</u> <u>ft</u>	<u>DFI minus</u> <u>Kalman, ft</u>	<u>OI minus</u> <u>Kalman, ft</u>	<u>SCA minus</u> <u>Kalman, ft</u>	<u>Theodolite</u> <u>(Z), ft</u>	<u>Kalman</u> <u>(Z), ft</u>	<u>Theodolite-</u> <u>Kalman, ft</u>
15:51:56	57116	9274	9356		9794	-520	-438		7560.5	7561	0
15:52:18	57138	4267	4156		4553	-286	-397		2326.2	2329	-3
15:52:21	57141	3696	3676		3969	-273	-293		1746.3	1746	0
15:52:26	57146	2963	3061		3204	-241	-143		981.4	981	0
15:52:29	57149	2732	2821		2863	-131	-42		641.6	641	0
15:52:31	57151	2448	2546		2680	-232	-134		461.1	458	3

TABLE A-XII.- UPPER AIR DATA FOR FREE FLIGHT 4

<u>True altitude, ft</u>	<u>62 standard altitude, ft</u>	<u>62 standard minus true, ft</u>
2375	2175	-200
3000	2774	-226
4000	3735	-265
5000	4699	-301
6000	5645	-355
7000	6600	-400
8000	7555	-445
9000	8490	-510
10000	9463	-537
11000	10426	-574
12000	11381	-619
13000	12333	-667
14000	13300	-700
15000	14258	-742
16000	15230	-770
17000	16200	-800
18000	17150	-850
19000	18129	-871
20000	19100	-900
21000	20060	-940
22000	21031	-969
23000	22000	-1000
24000	22982	-1018
25000	23959	-1041
26000	24931	-1069
27000	25912	-1088
28000	26887	-1113
29000	27864	-1136
30000	28840	-1160

TABLE A-XIII.- ALTITUDE DATA FOR FREE FLIGHT 5

SGMT, hr:min:sec	SGMT, sec	DFI, ft	OI, ft	SCA, ft	Kalman, ft	DFI minus Kalman, ft	OI minus Kalman, ft	SCA minus Kalman, ft	Theodolite (Z), ft	Kalman (Z), ft	Theodolite- Kalman (Z), ft
15:00:36	54036	2317	2321	2281	2288	29	33	- 7			
15:00:48	54048	2314	2316	2266	2286	28	30	-20			
15:01:00	54060	2380	2391	2305	2313	67	78	- 8			
15:01:37	54097	2861	2866	2779	2772	89	94	7			
15:02:08	54128	3413	3466	3366	3364	49	102	2			
15:02:29	54149	3835	3906	3777	3780	55	126	- 3			
15:03:00	54160	4758	4806	4703	4698	70	108	5			
15:03:55	54235	6014	6006	5935	5989	25	17	- 54			
15:05:00	54300	7287	7306	7199	7285	2	21	- 86			
15:06:13	54373	8571	8706	8508	8689	-118	17	-181			
15:07:41	54461	9911	10006	9838	10063	-152	- 57	-225			
15:12:42	54762	13885	13856	13776	14108	-223	-252	-332			
15:14:27	54867	14804	14806	14685	15090	-286	-284	-405			
15:15:29	54929	15369	15406	15261	15724	-355	318	-463			
15:16:34	54995	15963	16006	15850	16326	-363	-326	-476			
15:18:01	55081	16597	16656	16472	17056	-459	-400	-584			
15:19:00	55140	16994	16906	16858	17484	-490	-578	-626			
15:21:00	55260	17523	17506	17374	18041	-518	-535	-667			
15:22:01	55321	17876	17856	17731	18411	-535	-555	-680			
15:24:00	55440	18605	18656	18458	19148	-543	-492	-690			
15:27:04	55624	19286	19256	19133	19830	-544	-574	-697			
15:29:00	55740	19513	19556	19368	20094	-581	-538	-726			
15:32:01	55921	19970	20006	19831	20634	-664	-628	-803			
15:33:11	55991	20148	20156	19998	20798	-650	-642	-800			
15:35:00	56100	20310	20306	20153	20985	-675	-679	-832			
15:37:00	56220	20589	20606	20431	21267	-678	-661	-836			
15:39:09	56340	20955	20956	20788	21665	-710	-709	-877			
15:41:08	56468	21219	21206	21055	21905	-686	-699	-850			
15:44:23	56663	21501	21456	21325	22201	-700	-745	-875			
15:47:04	56824	21907	21906	21721	22637	-730	-731	-916			
15:48:00	56880	21894	21956	21728	22635	-741	-679	-907			
15:51:54	57114	21879	21906	21732	22712	-833	-806	-980			
15:51:56	57116	21882	21906	21732	22707	-825	-801	-975			
15:52:12	57132	21210	21256	21079	22085	-875	-829	-1006			
15:52:21	57141	20421	20456	20309	21261	-840	-805	-952			
15:52:31	57151	19557	19506	19399	20332	-775	-826	-933			
15:52:39	57159	18762	18756	18686	19518	-756	-762	-832			
15:52:49	57169	18318	18306	17807	19164	-846	-858	-1357	16879.5	16857	22
15:52:57	57179	17196	17156	Sep.	17665	-469	-509		15809.8	15370	440
15:53:04	57184	15595	15356		16418	-823	-1062		14154.7	14128	27
15:53:09	57189	14545	14406		15299	-754	-893		13038.2	13015	23
15:53:12	57192	13970	13706		14677	-707	-971		12416.8	12396	21
15:53:16	57196	13163	13056		13838	-675	-782		11576.6	11561	16
15:53:19	57199	12551	12506		13208	-657	-702		10949.7	10934	16
15:53:22	57202	11973	11956		12582	-609	-626		10327.1	10310	17
15:53:26	57206	11170	11506		11732	-562	-226		9486.3	9464	22
15:53:28	57208	10770	11106		11320	-550	-214		9069.6	9053	17
15:53:32	57212	9563	10256		10487	-524	-231		8238.5	8224	15
15:53:35	57215	9353	9606		9863	-510	-257		7615.6	7602	14
15:53:38	57218	8772	8606		9240	-468	-634		6993.8	6980	14
15:53:42	57222	7973	7856		8409	-436	-553		6160.6	6152	8
15:53:46	57226	7190	7006		7568	-388	-562		5321.0	5313	9

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TABLE A-XIII.- Concluded

<u>SGMT,</u> <u>hr:min:sec</u>	<u>SGMT,</u> <u>sec</u>	<u>DFI,</u> <u>ft</u>	<u>OI,</u> <u>ft</u>	<u>SCA,</u> <u>ft</u>	<u>Kalman,</u> <u>ft</u>	<u>DFI minus</u> <u>Kalman, ft</u>	<u>OI minus</u> <u>Kalman, ft</u>	<u>SCA minus</u> <u>Kalman, ft</u>	<u>Theodolite</u> <u>(Z), ft</u>	<u>Kalman</u> <u>(Z), ft</u>	<u>Theodolite-</u> <u>Kalman (Z), ft</u>
15:53:48	57228	6783	6606		7151	-368	-545		4905.2	4896	9
15:53:52	57232	5979	5856		6315	-337	-459		4065.2	4062	4
15:53:54	57234	5557	5406		5880	-323	-474		3629.0	3628	1
15:53:57	57237	4883	4756		5199	-316	-443		2950.5	2948	2
15:53:59	57239	4444	4306		4738	-294	-432		2491.1	2487	4
15:54:01	57241	4031	3956		4283	-252	-327		2047.8	2033	15
15:54:02	57242	3856	3756		4078	-222	-322		1841.7	1828	14
15:54:07	57247	3056	2936		3067	- 11	-131		975.1	944	31
15:54:11	57251	2614	2521		2719	-105	102		487.0	471	16
15:54:17	57257	2313	2411		2351	- 38	60		119.8	104	16
15:54:22	57262	2274	2351		2275	- 1	- 24		55.0	28	27
15:54:38	57278	2262	2266		2276	- 14	- 10		32.0	28	4

TABLE A-XIV.- UPPER AIR DATA FOR FREE FLIGHT 5

<u>True altitude, ft</u>	<u>62 standard altitude, ft</u>	<u>62 standard minus true, ft</u>
2375	2366	-9
3000	2981	-19
4000	3945	-55
5000	4899	-101
6000	5851	-149
7000	6804	-196
8000	7758	-242
9000	8712	-288
10000	9668	-332
11000	10626	-374
12000	11579	-421
13000	12530	-470
14000	13478	-522
15000	14425	-575
16000	15270	--
17000	16315	-685
18000	17259	-741
19000	18201	-799
20000	19145	-855
21000	20088	-912
22000	21032	-968
23000	21978	-1022
24000	22925	-1075
25000	23875	-1125
26000	24827	-1173
27000	25781	-1213
28000	26740	-1260
29000	27699	-1301
30000	28655	-1345
31000	29609	-1391
32000	30562	-1438
33000	31515	-1485
34000	32468	-1532
35000	33424	-1576

APPENDIX B

ALTITUDE COMPARISON DATA FIGURES

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FIGURES

Figure		Page
B-1	Radar altimeter altitude minus Kalman altitude	B-5
B-2	MLS altitude minus Kalman altitude	B-6
B-3	Theodolite altitude minus Kalman altitude (FF1)	B-7
B-4	Theodolite altitude minus Kalman altitude (FF3)	B-8
B-5	Theodolite altitude minus Kalman altitude (FF4)	B-9
B-6	Theodolite altitude minus Kalman altitude (FF5)	B-10
B-7	OI altitude minus Kalman altitude (CA3)	B-11
B-8	OI altitude minus Kalman altitude (FF1)	B-12
B-9	OI altitude minus Kalman altitude (FF2)	B-13
B-10	OI altitude minus Kalman altitude (FF3)	B-14
B-11	OI altitude minus Kalman altitude (FF4)	B-15
B-12	OI altitude minus Kalman altitude (FF5)	B-16
B-13	DFI altitude minus Kalman altitude (CA3)	B-17
B-14	DFI altitude minus Kalman altitude (FF1)	B-18
B-15	DFI altitude minus Kalman altitude (FF2)	B-19
B-16	DFI altitude minus Kalman altitude (FF3)	B-20
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B-18	DFI altitude minus Kalman altitude (FF5)	B-22
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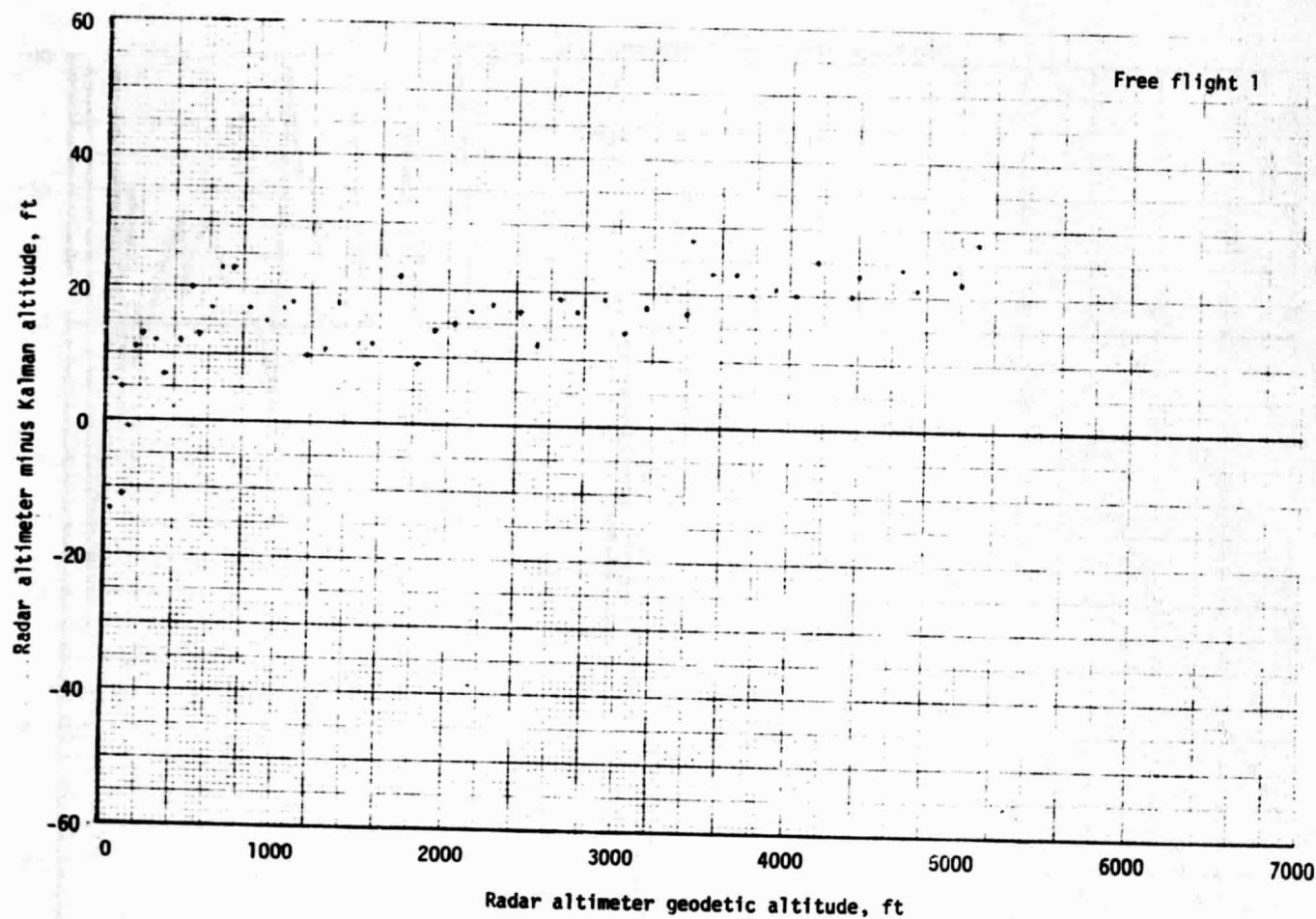


Figure B-1.- Radar altimeter altitude minus Kalman altitude.

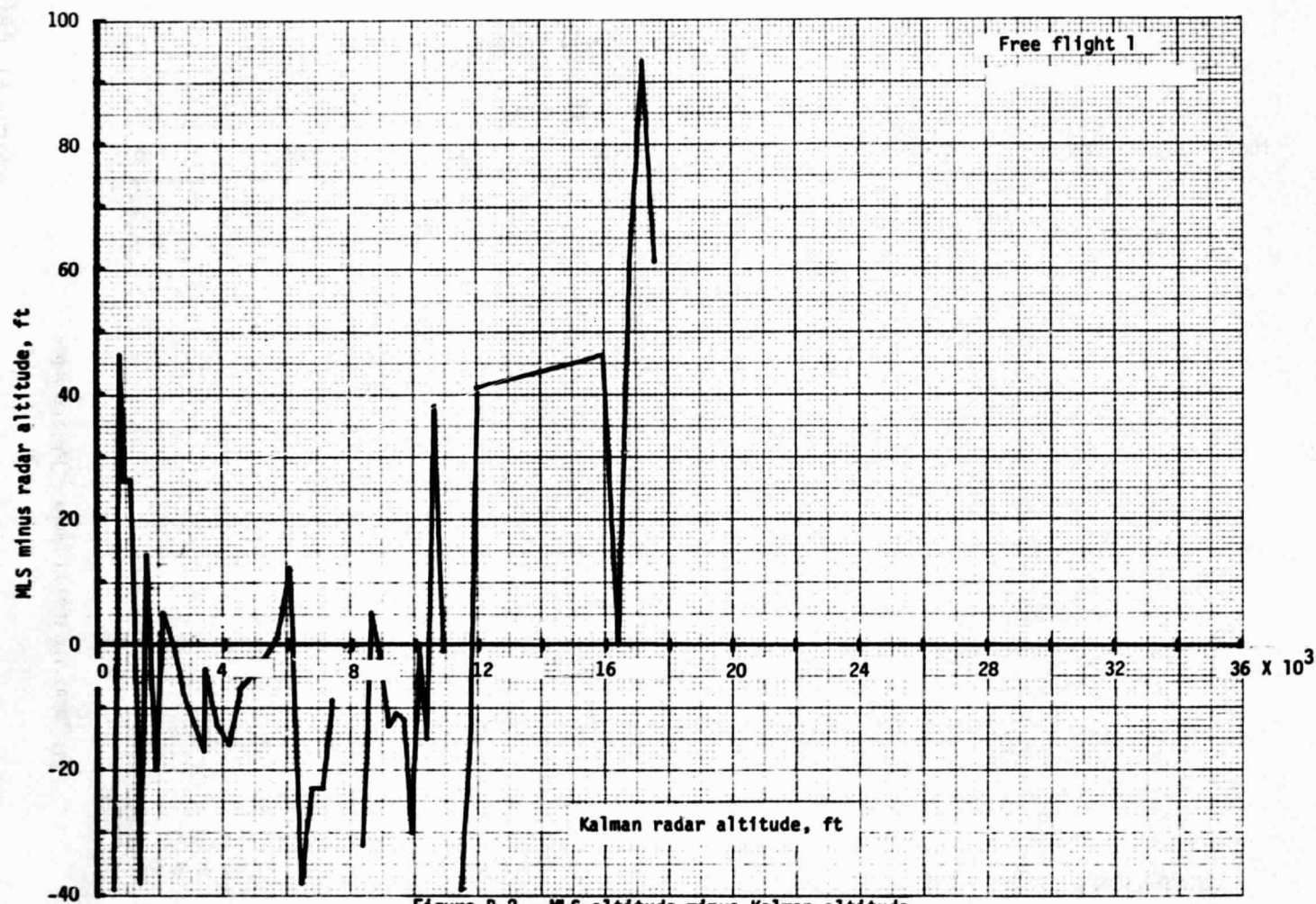


Figure B-2.- MLS altitude minus Kalman altitude.

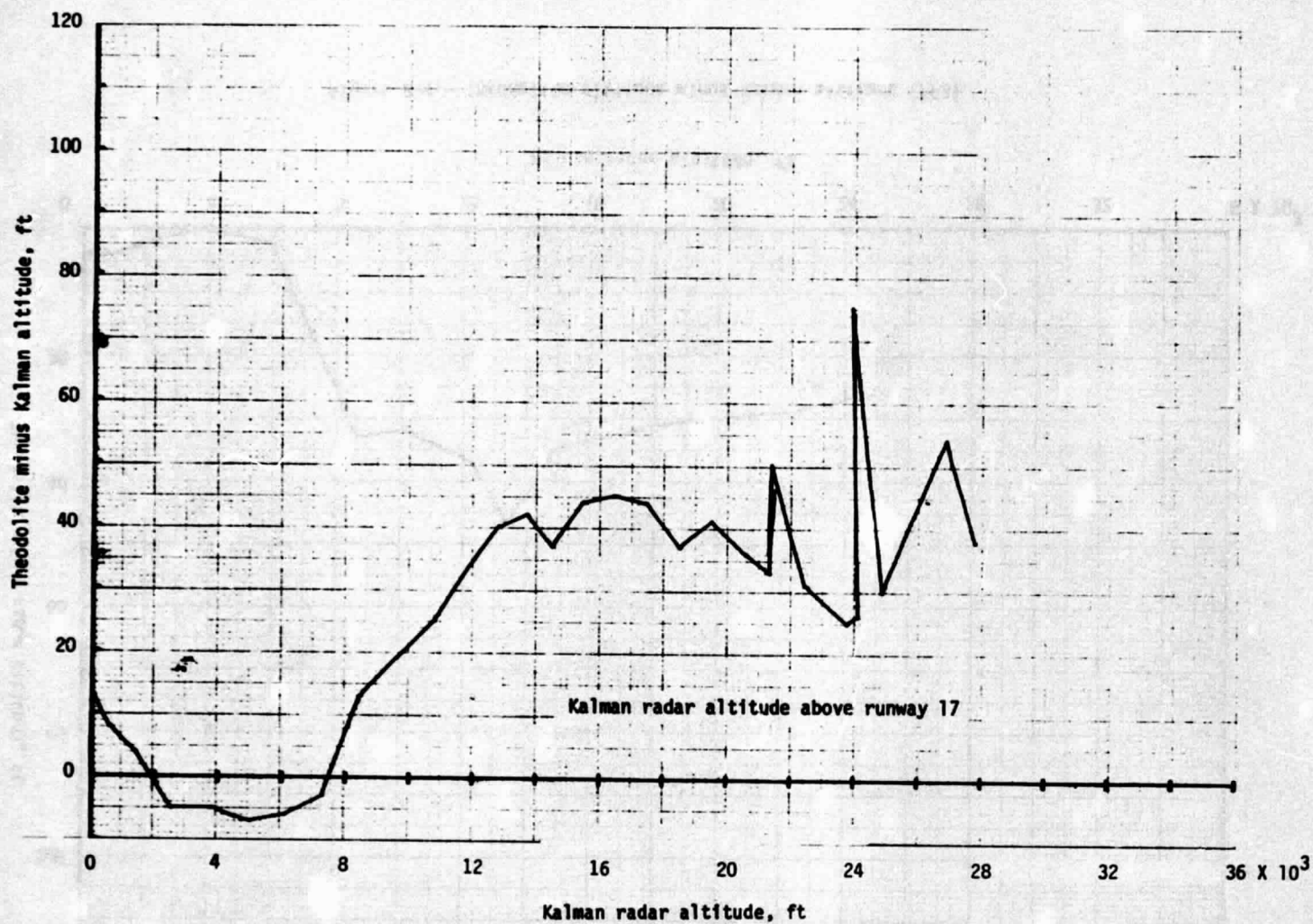


Figure B-3.- Theodolite altitude minus Kalman altitude (FF1).

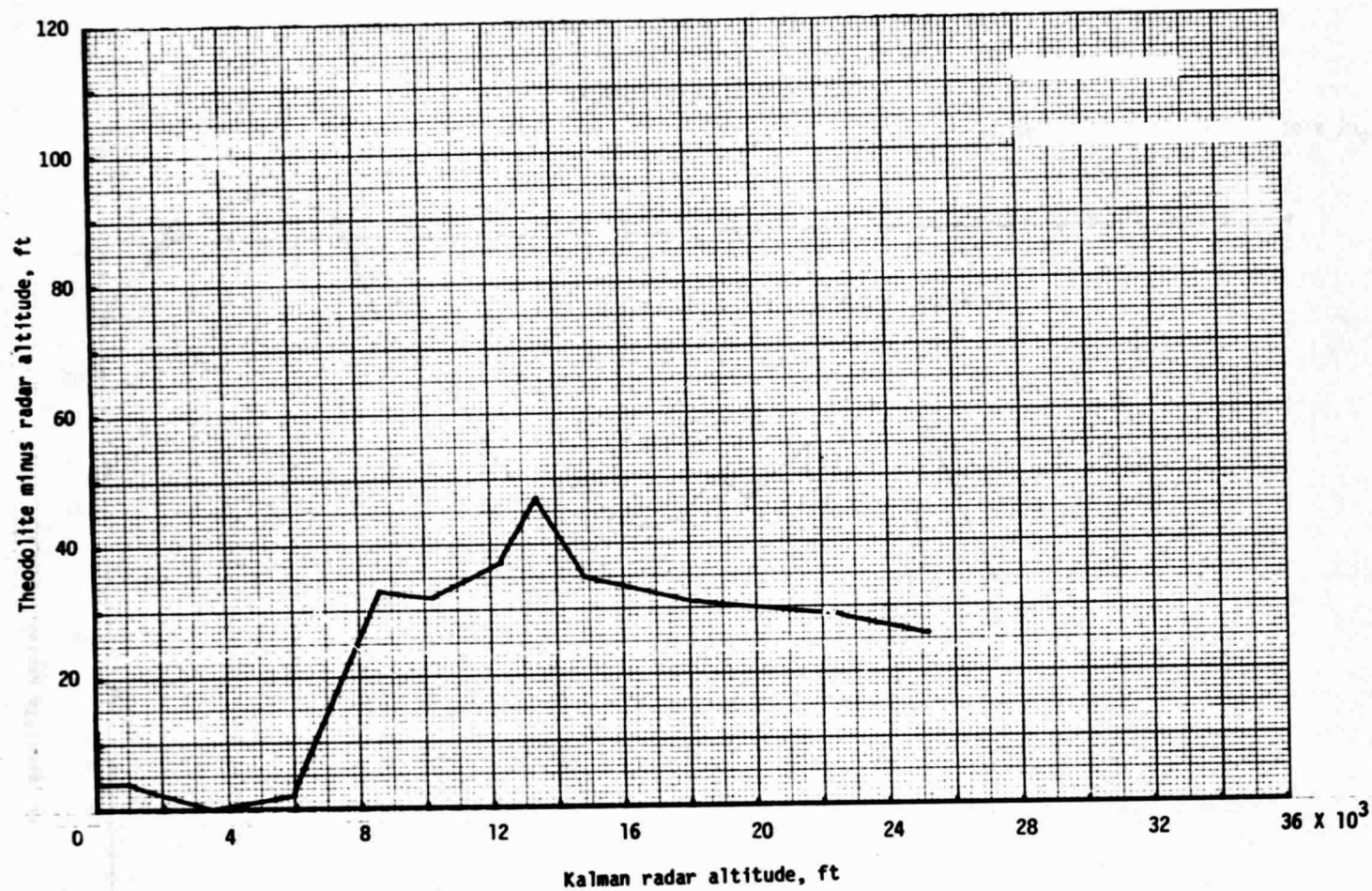


Figure B-4.- Theodolite altitude minus Kalman altitude (FF3).

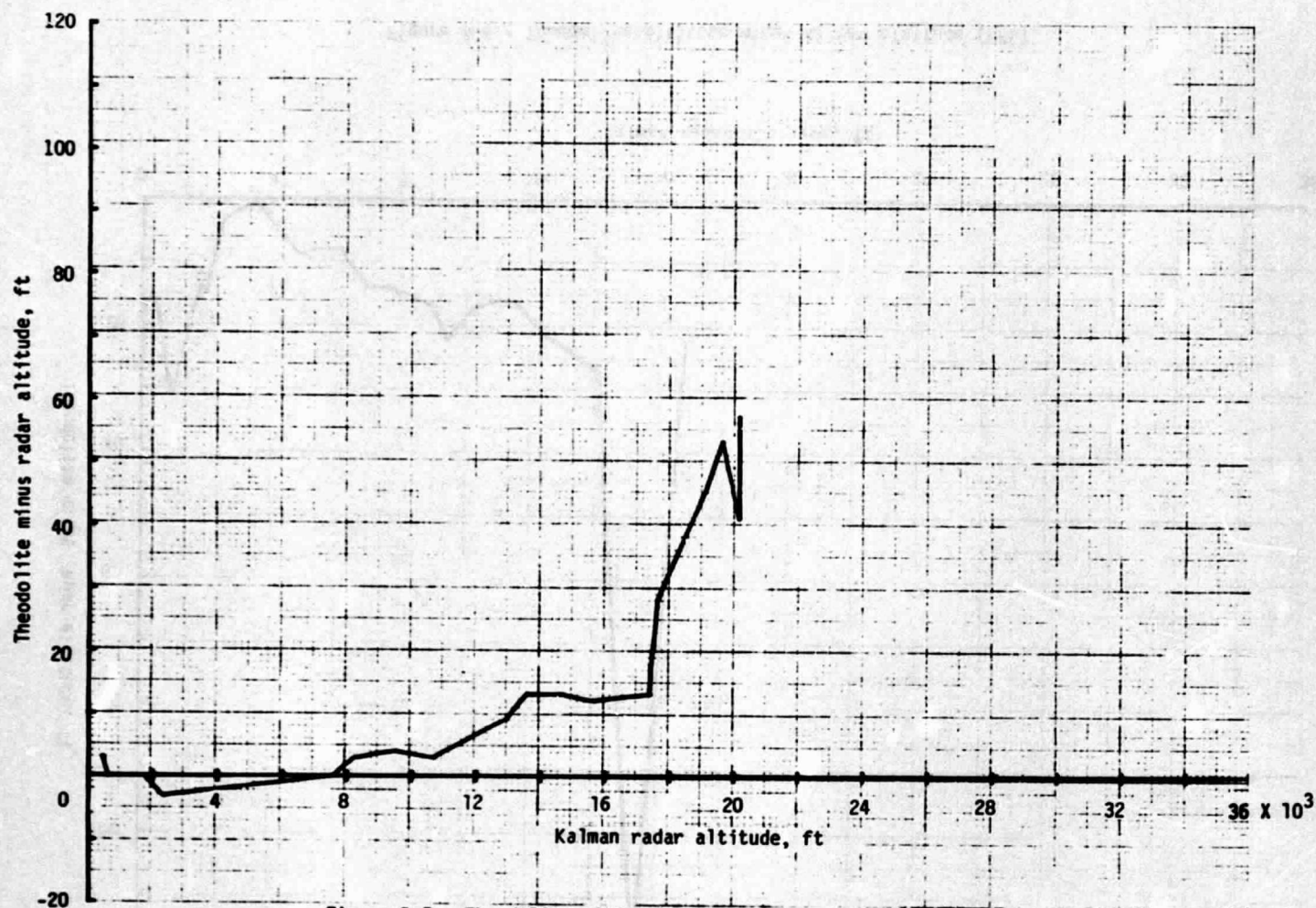


Figure B-5.- Theodolite altitude minus Kalman altitude (FF4).

01-B

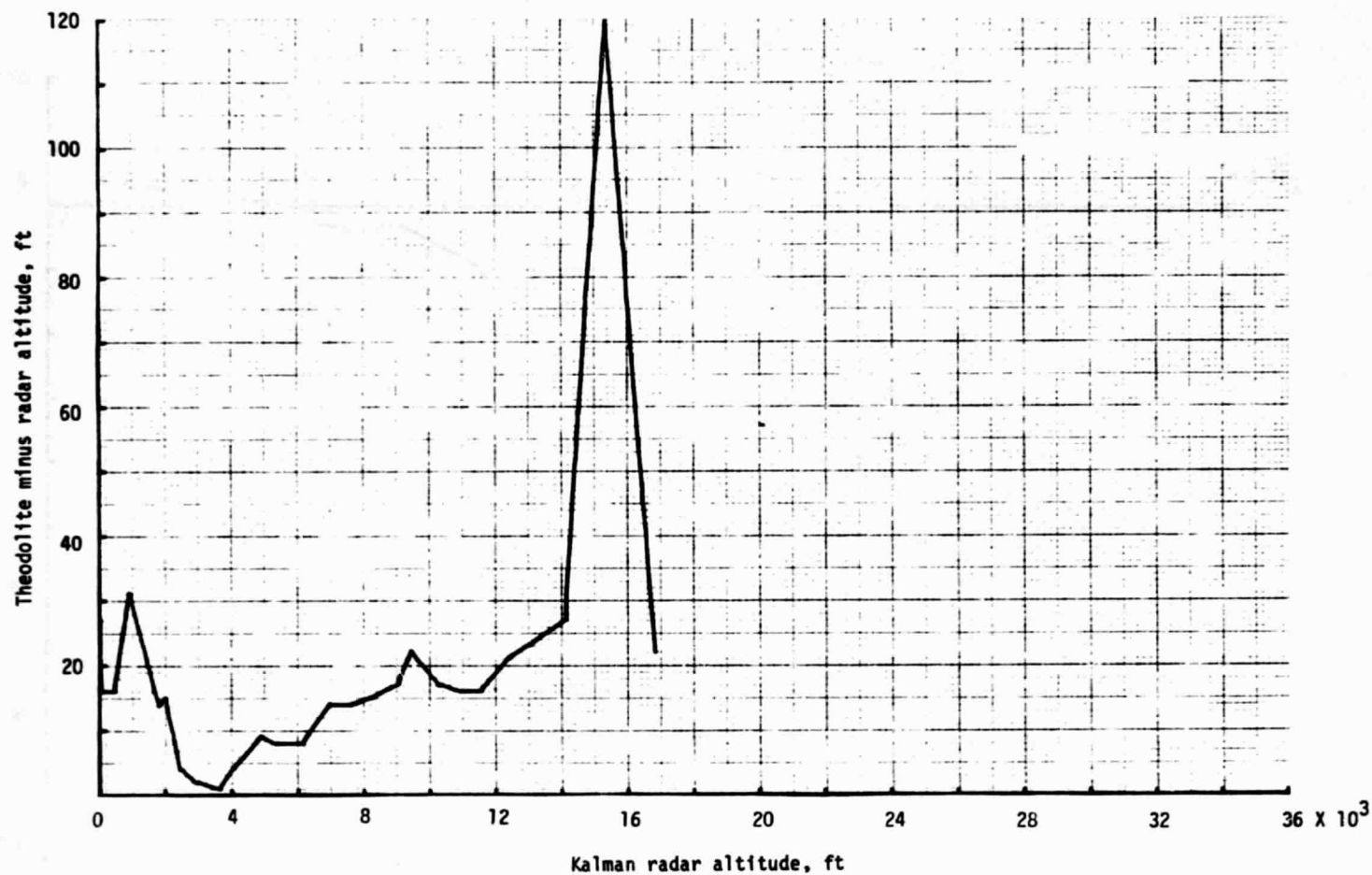


Figure B-6.- Theodolite altitude minus Kalman altitude (FF5).

B-11

OI altitude minus Kalman altitude, ft
62 standard minus true altitude, ft

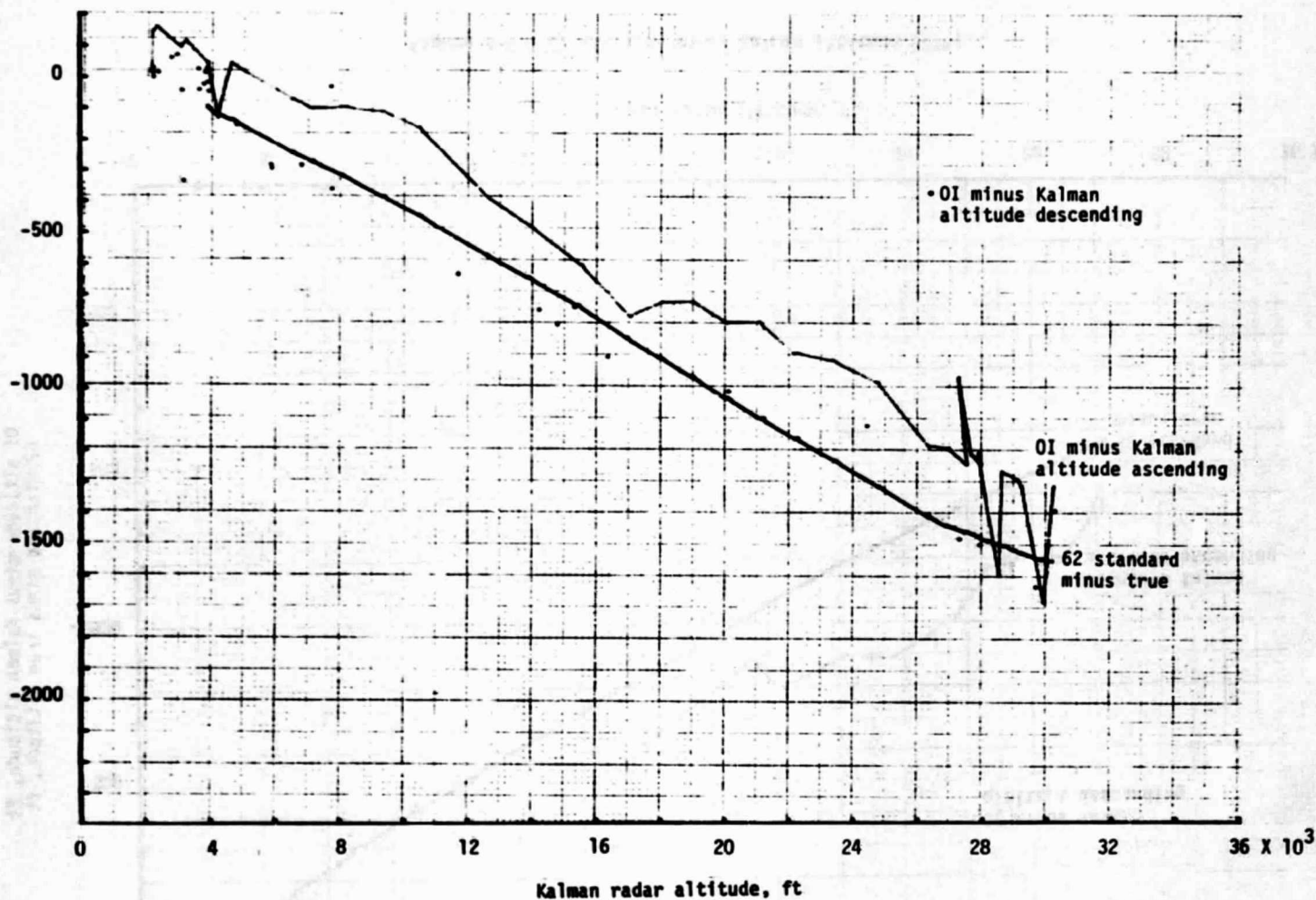


Figure B-7.- OI altitude minus Kalman altitude (CA3).

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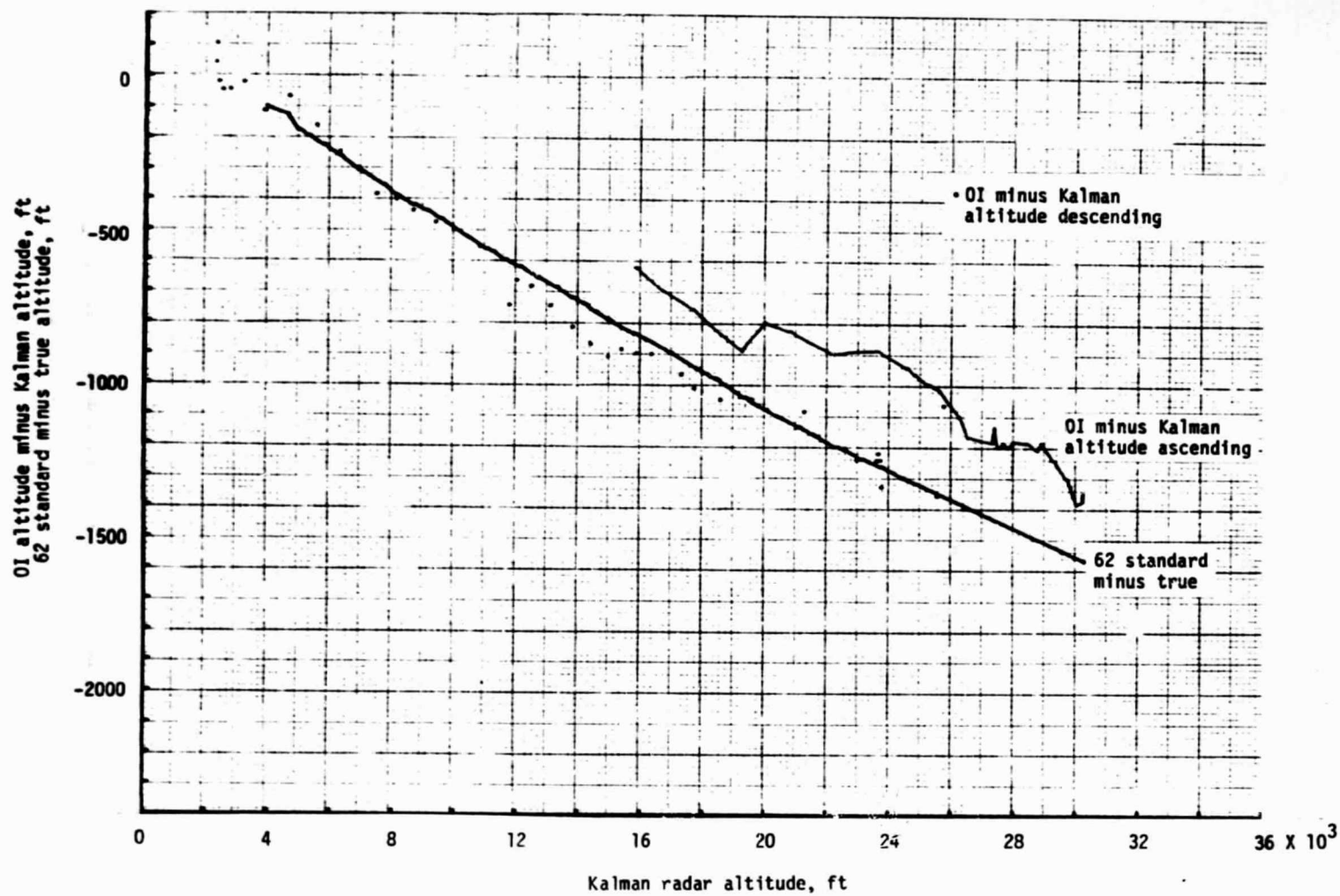


Figure B-8.- OI altitude minus Kalman altitude (FF1).

B-13

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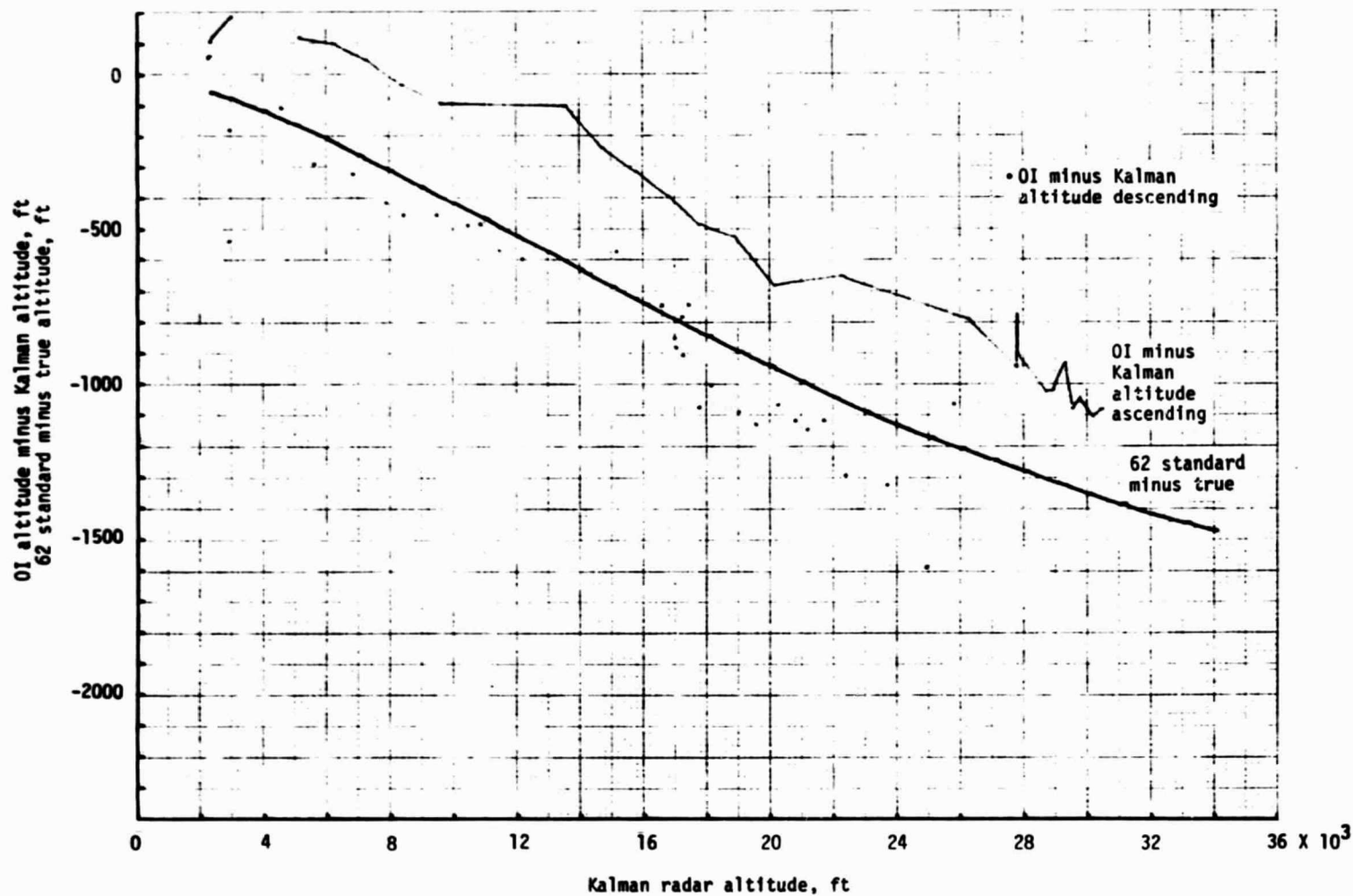


Figure B-9.- OI altitude minus Kalman altitude (FF2).

B-14

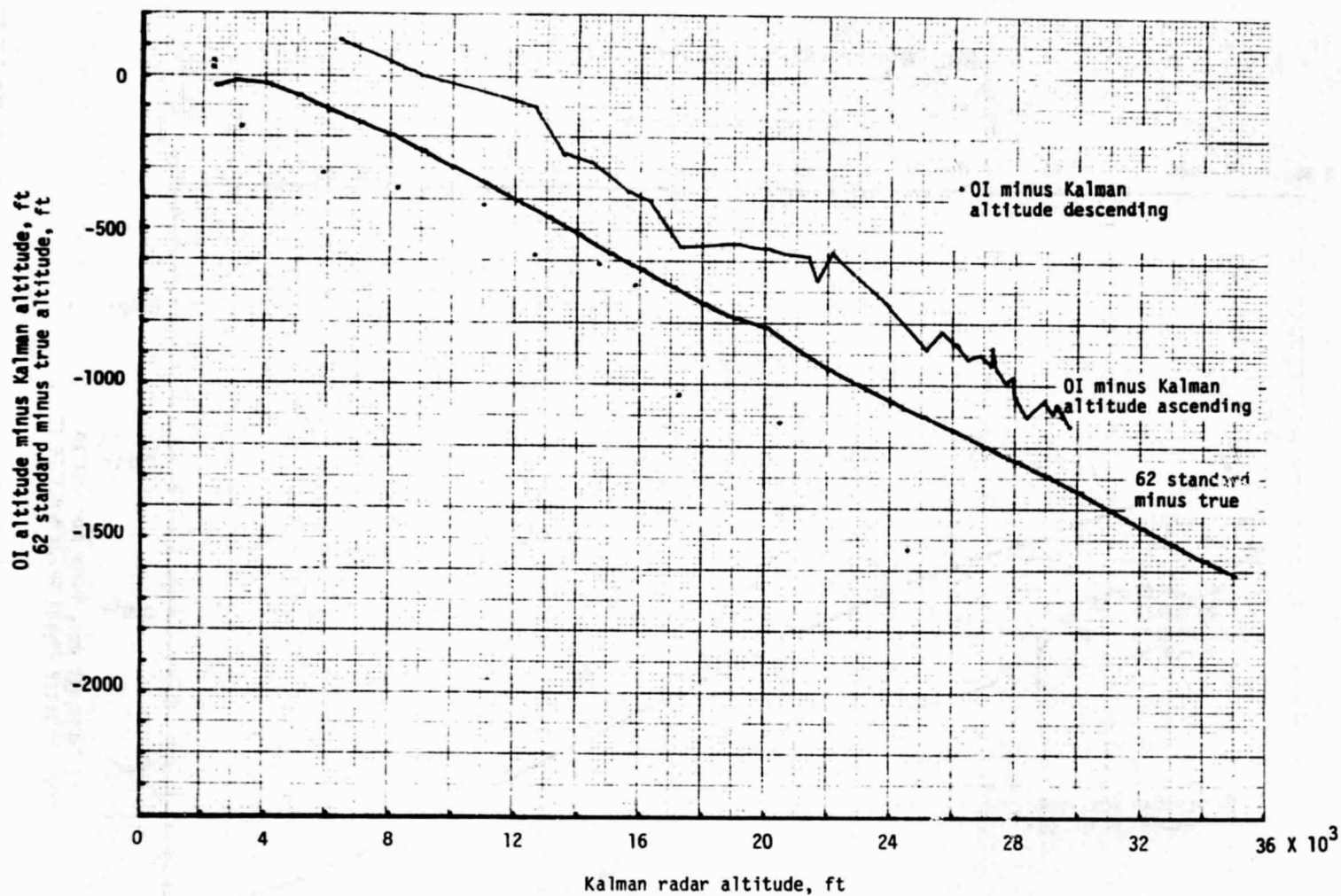


Figure B-10.- OI altitude minus Kalman altitude (FF3).

B-15

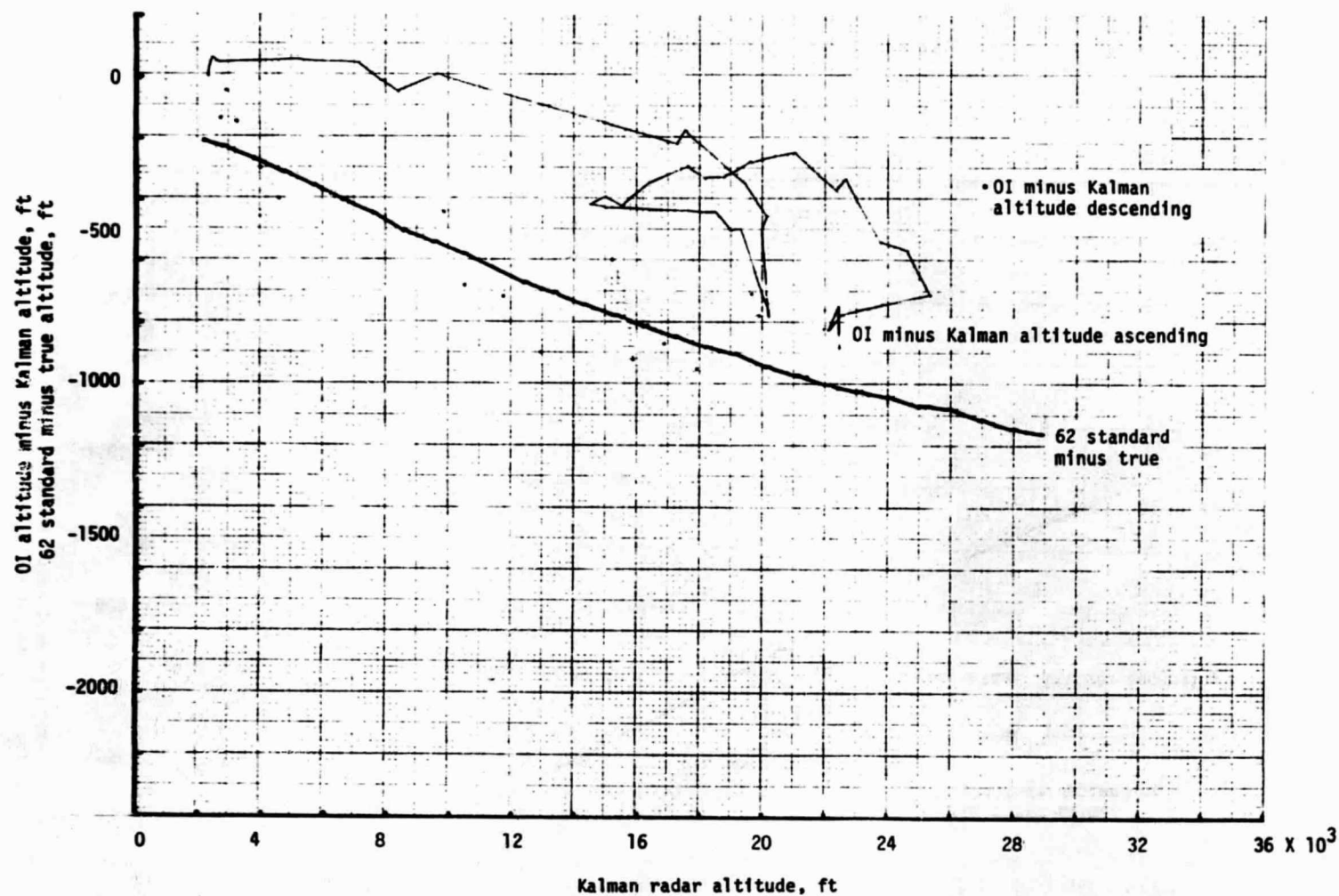


Figure B-11.- OI altitude minus Kalman altitude (FF4).

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OI altitude minus Kalman altitude, ft
62 standard minus true altitude, ft

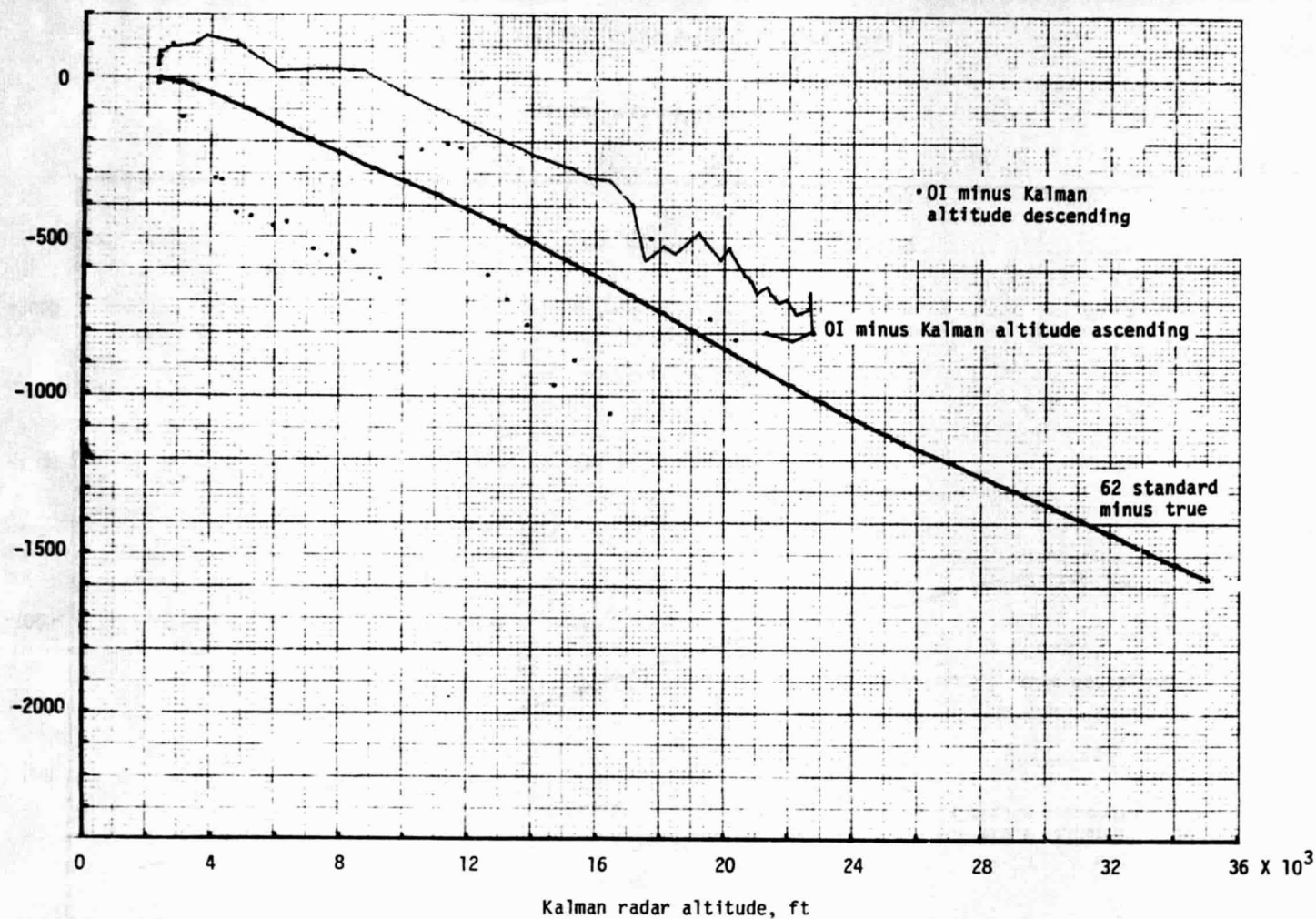


Figure B-12.- OI altitude minus Kalman altitude (FF5).

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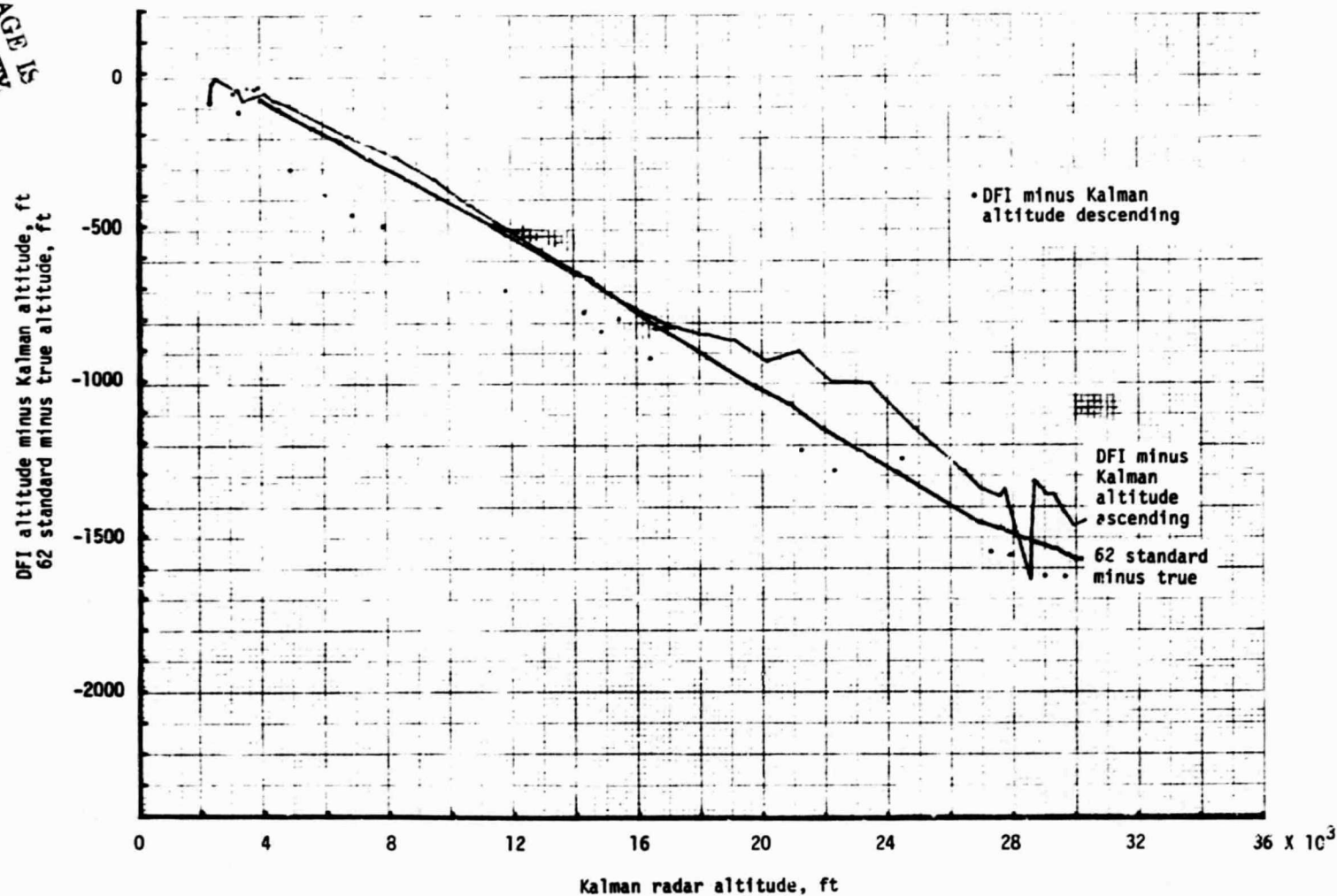


Figure B-13.- DFI altitude minus Kalman altitude (CA3).

B-18

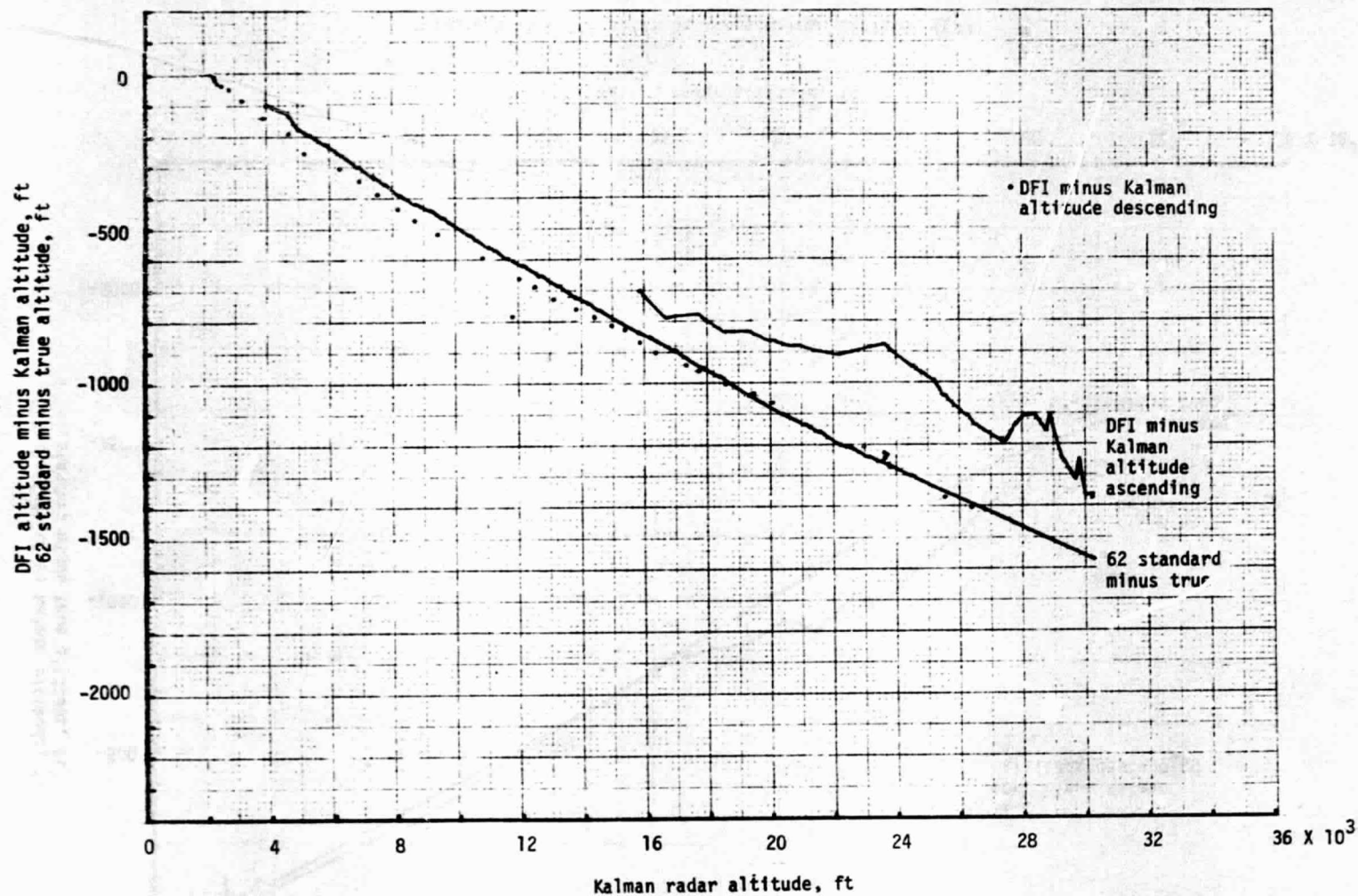


Figure B-14.- DFI altitude minus Kalman altitude (FF1).

B-19

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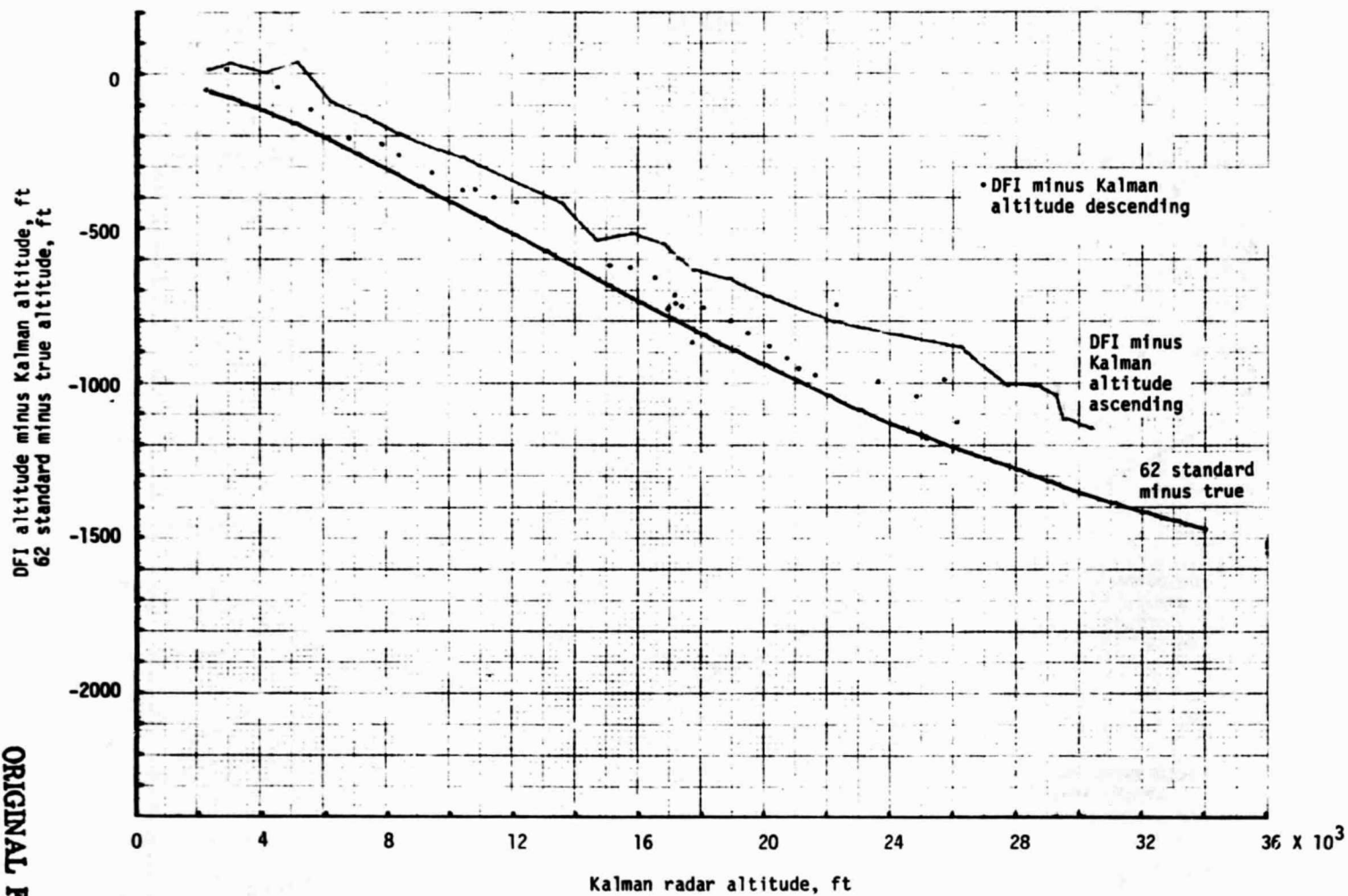


Figure B-15.- DFI altitude minus Kalman altitude (FF2).

B-20

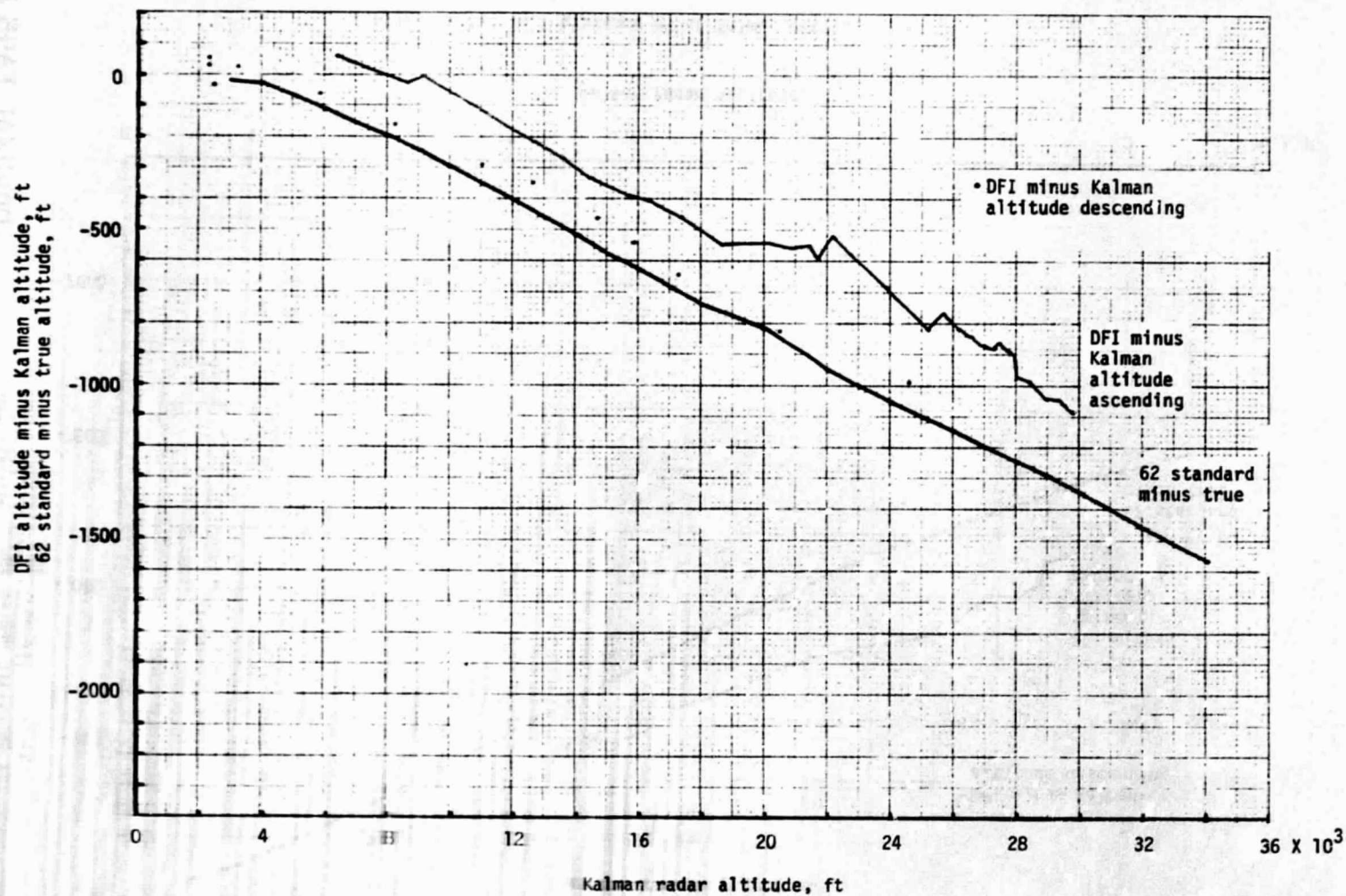


Figure B-16. - DFI altitude minus Kalman altitude (FF3).

B-21

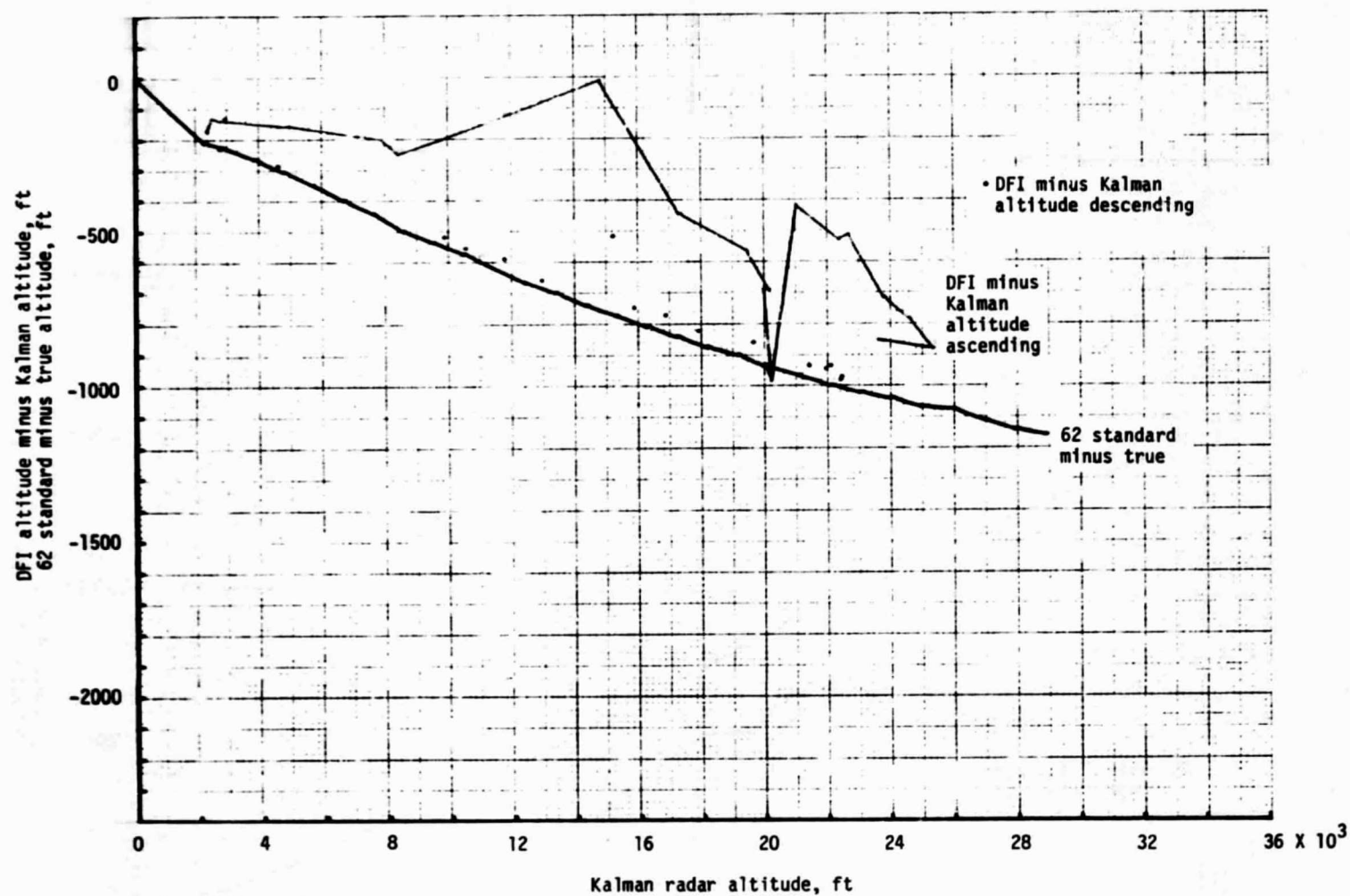


Figure B-17.- DFI altitude minus Kalman altitude (FF4).

B-22

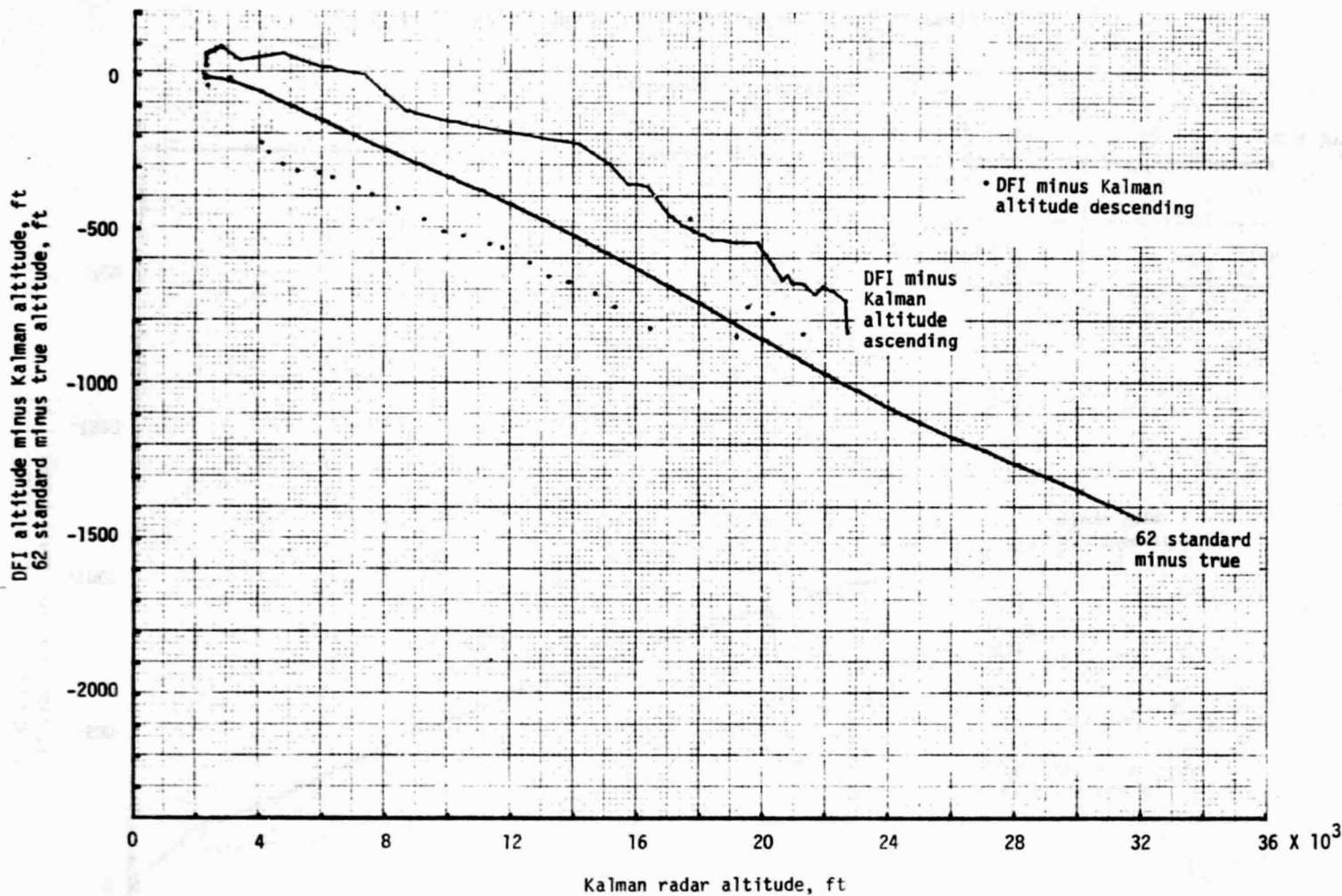


Figure B-18.- DFI altitude minus Kalman altitude (FF5).

B-23

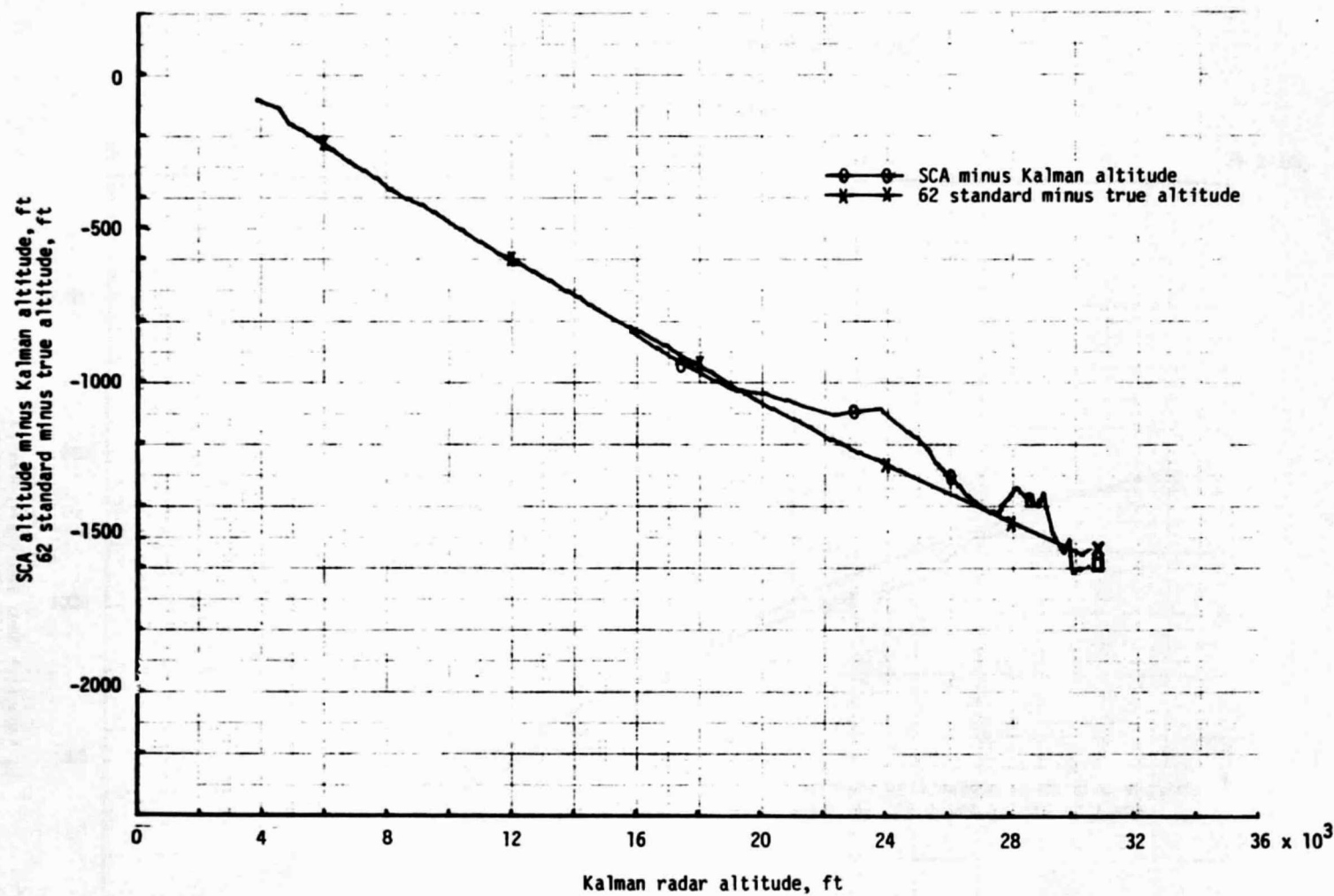


Figure B-19.- SCA altitude minus Kalman altitude (FF1).

B-24

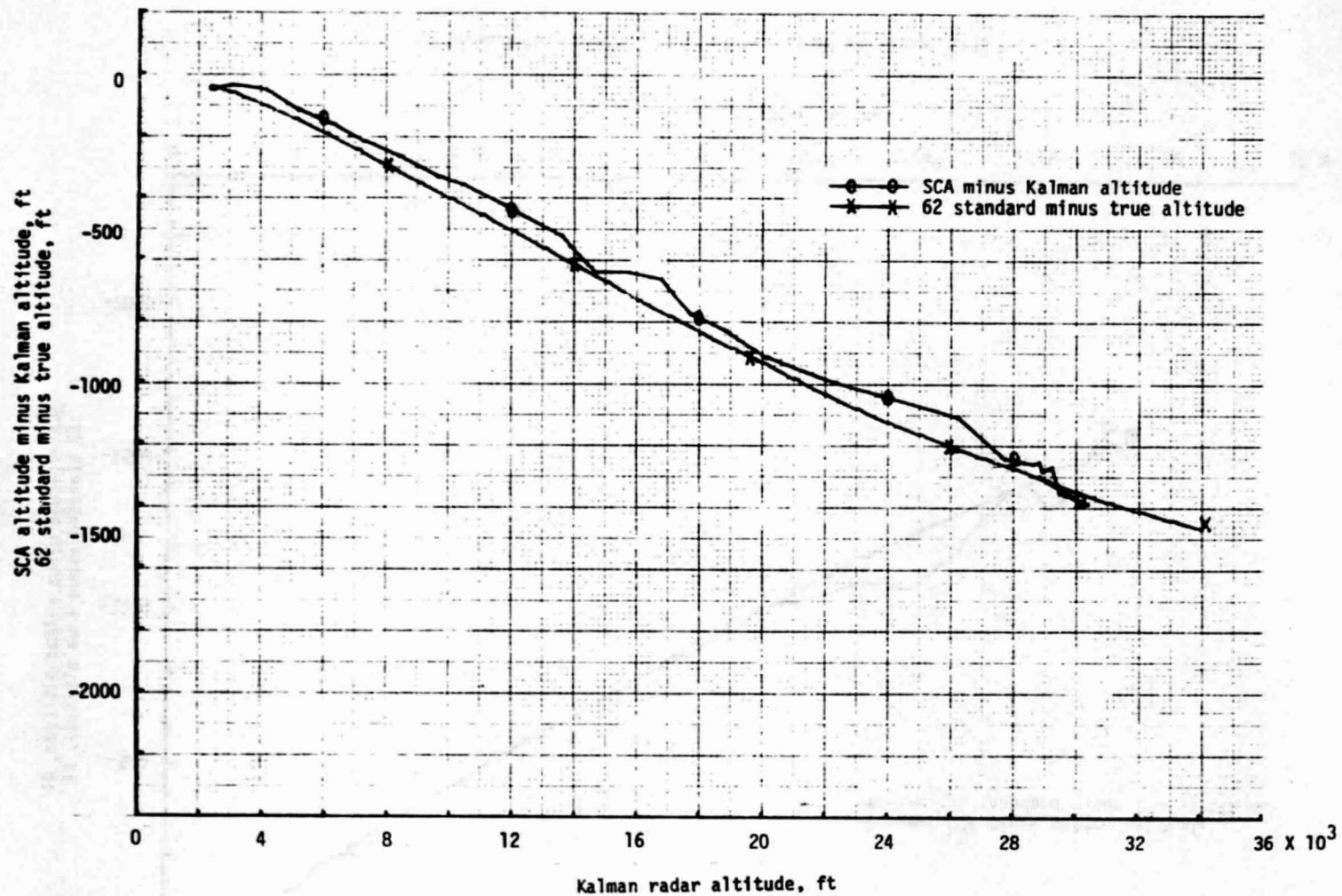


Figure B-20.- SCA altitude minus Kalman altitude (FF2).

B-25

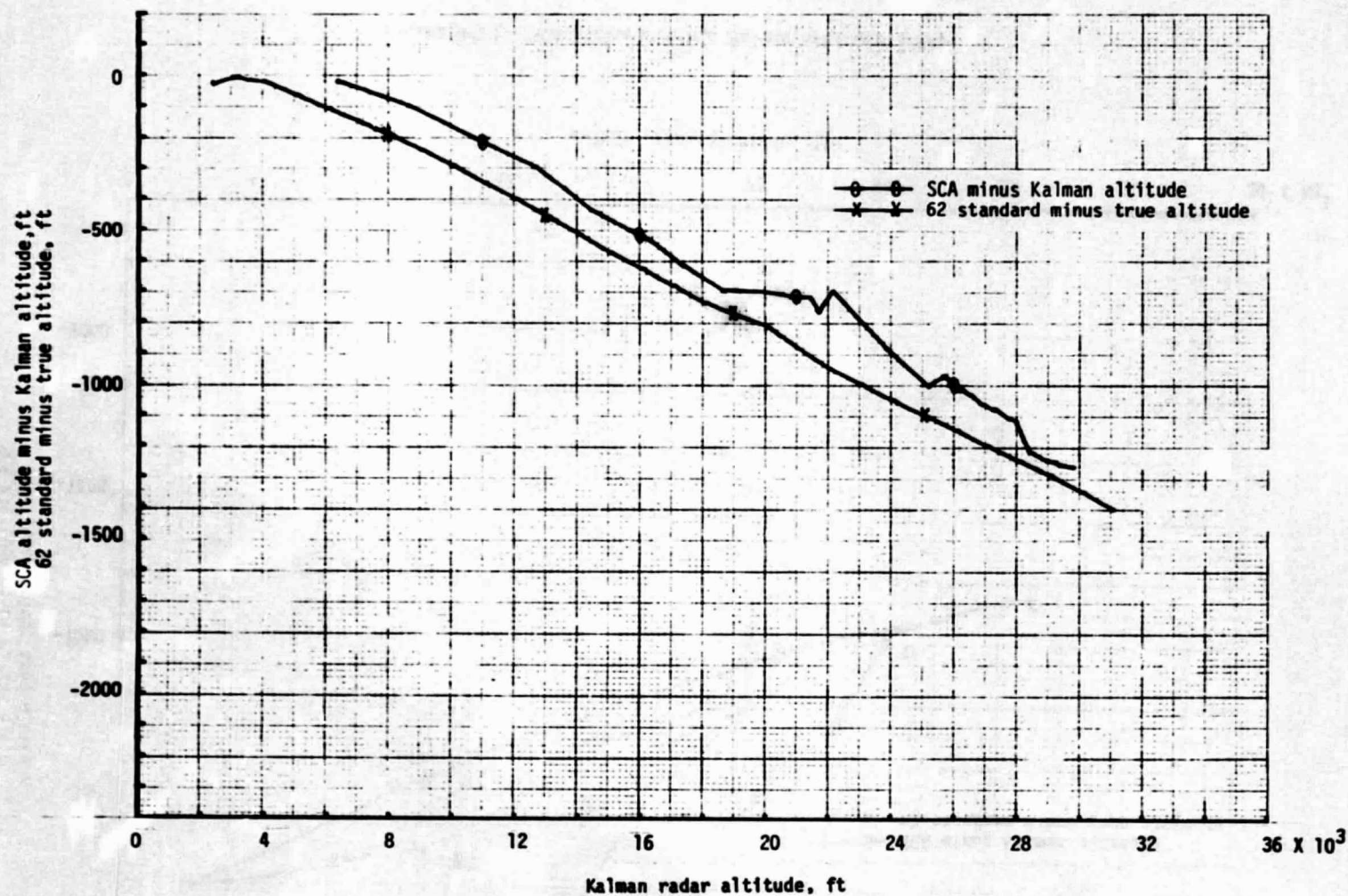


Figure B-21.- SCA altitude minus Kalman altitude (FF3).

B-26

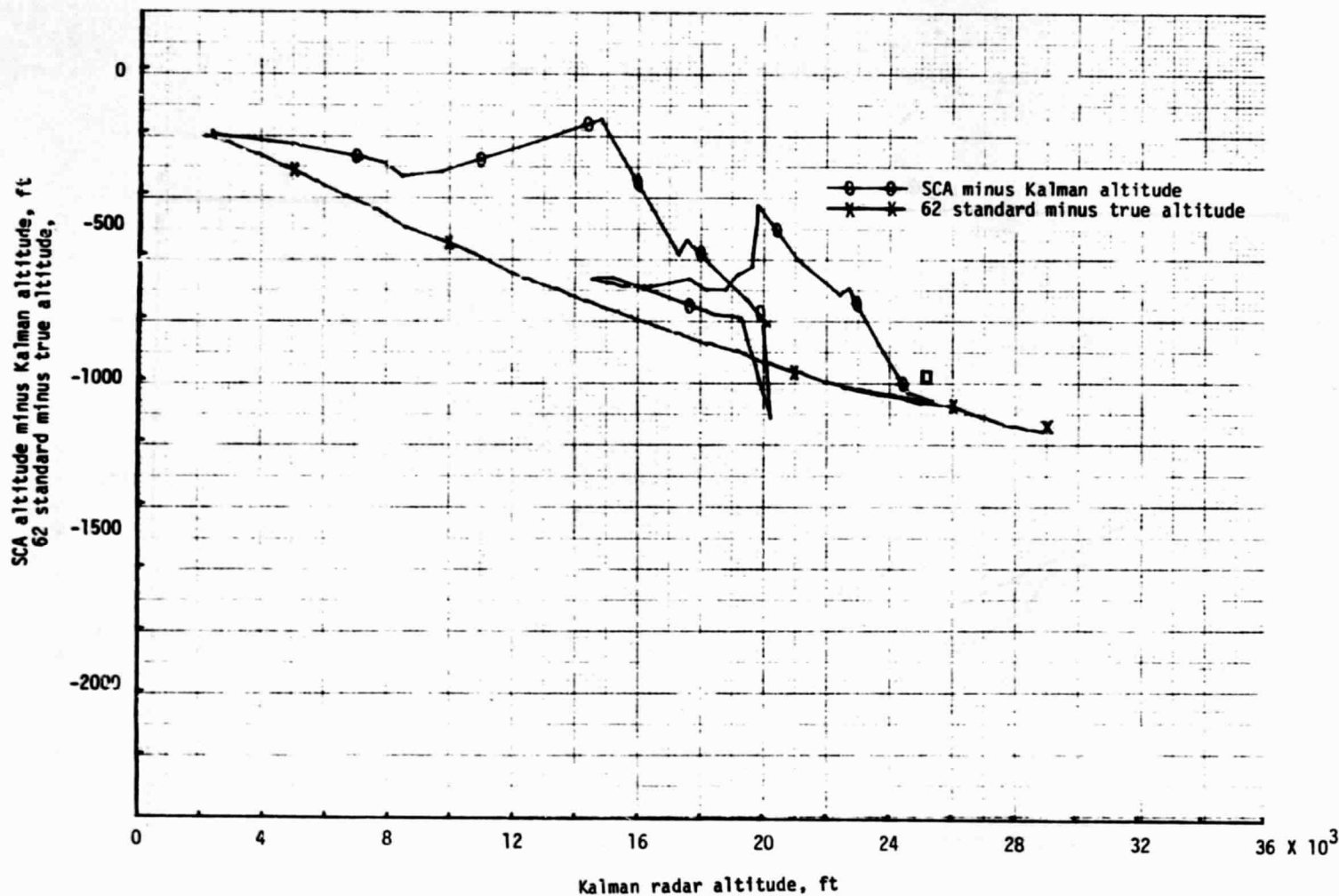


Figure B-22.- SCA altitude minus Kalman altitude (FF4).

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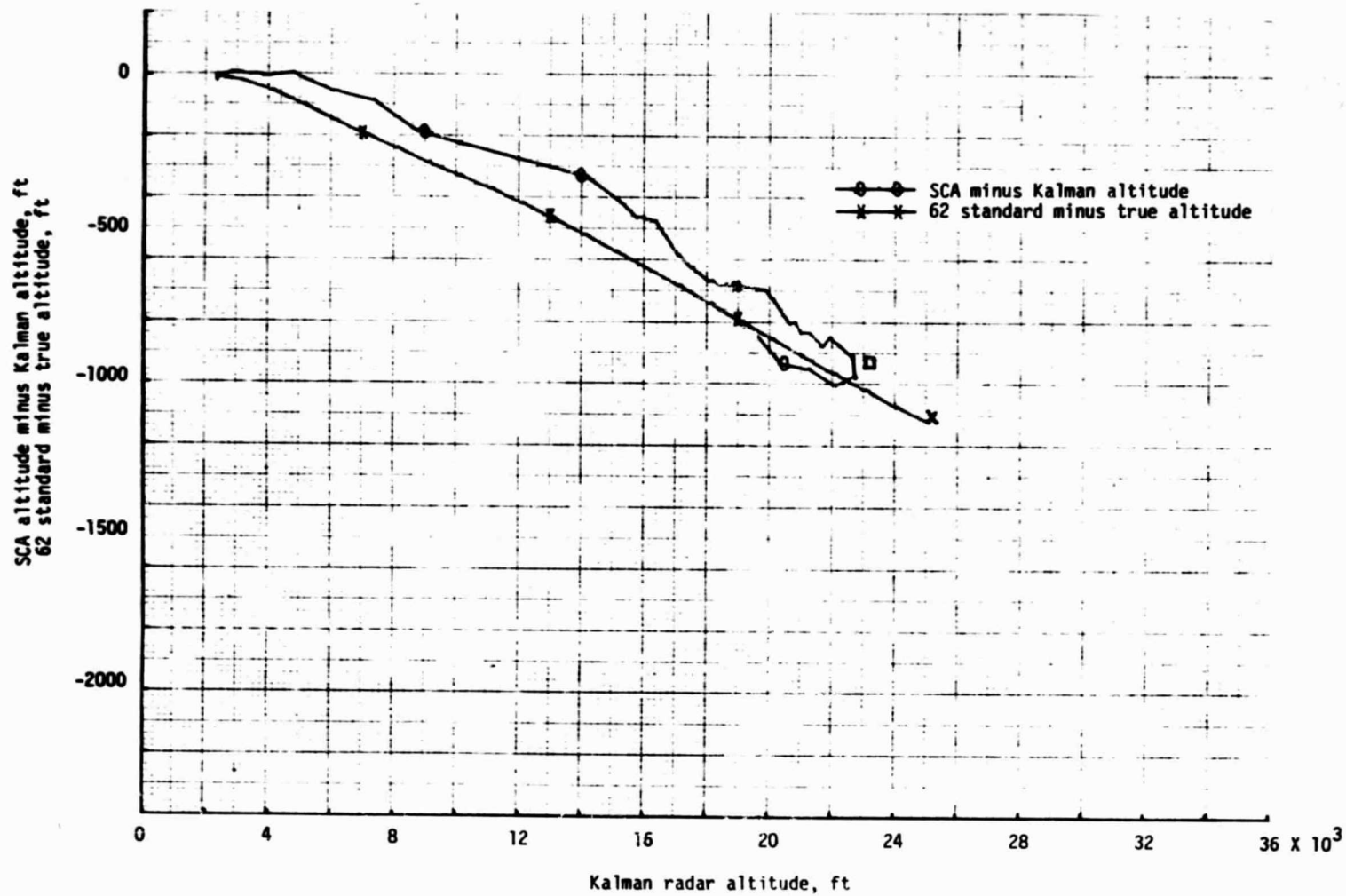


Figure B-23.- SCA altitude minus Kalman altitude (FF5).

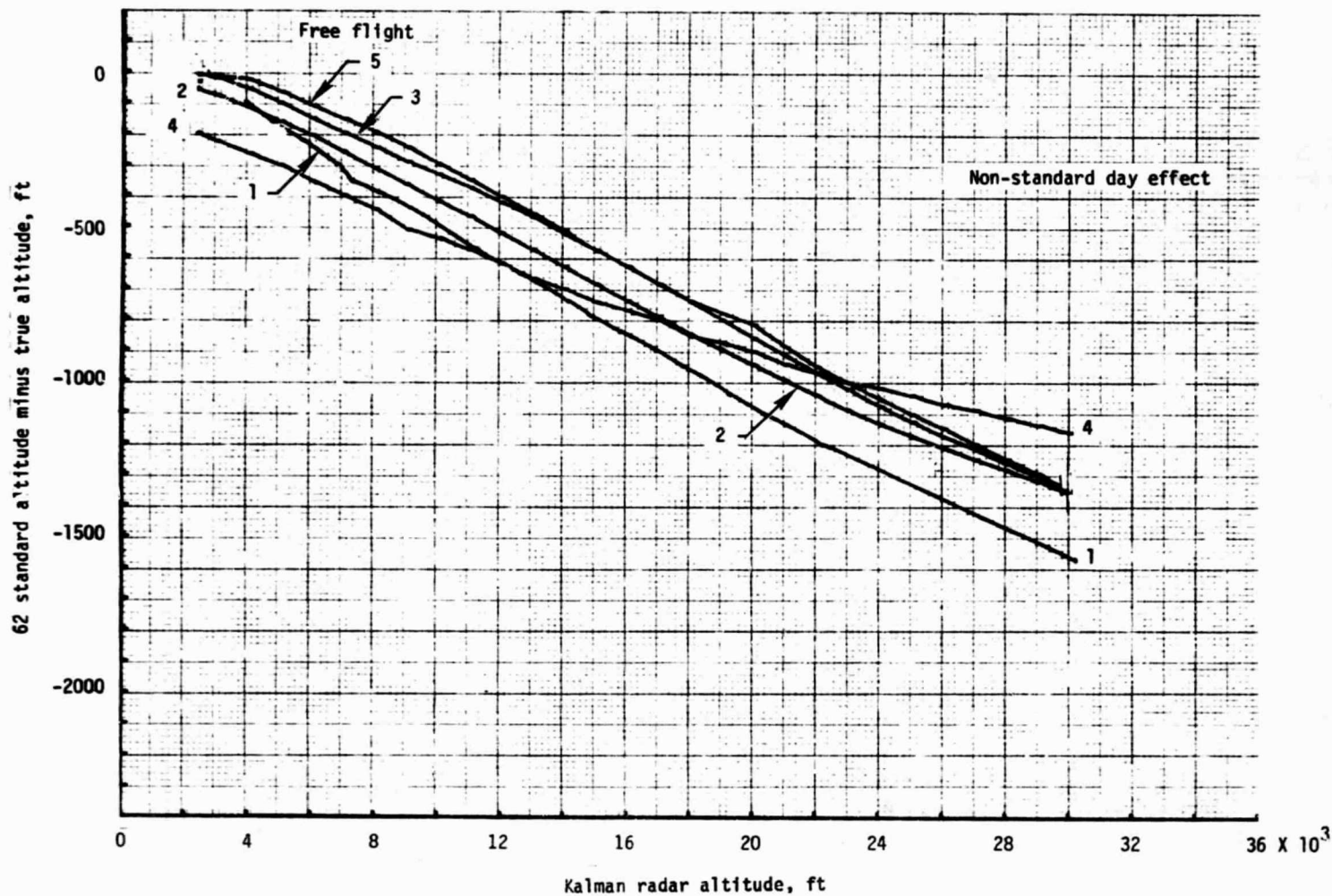


Figure B-24.- Non-standard day effect (free flights 1-5).

B-29

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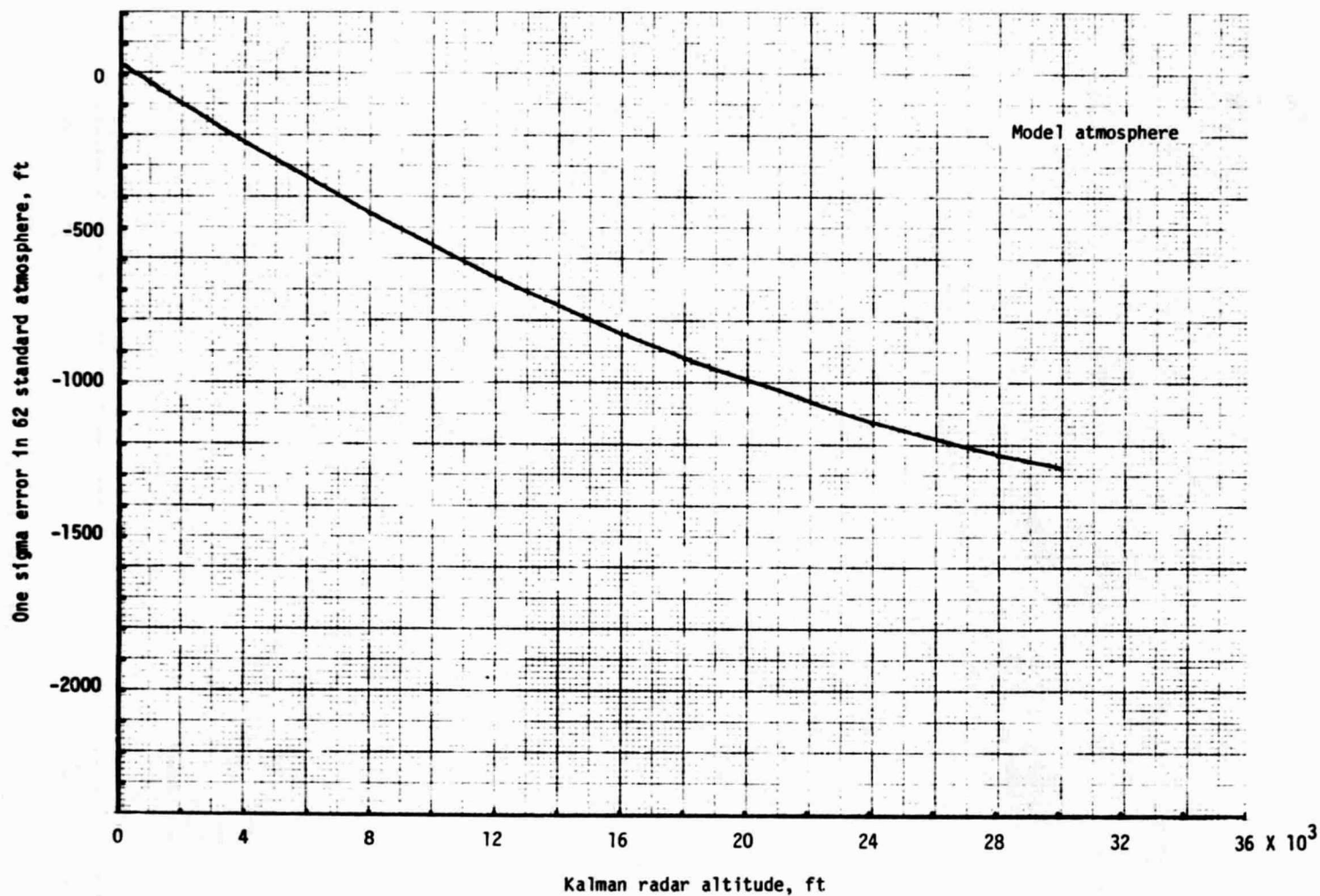


Figure B-25.- 62 standard atmosphere minus model atmosphere.

B-30

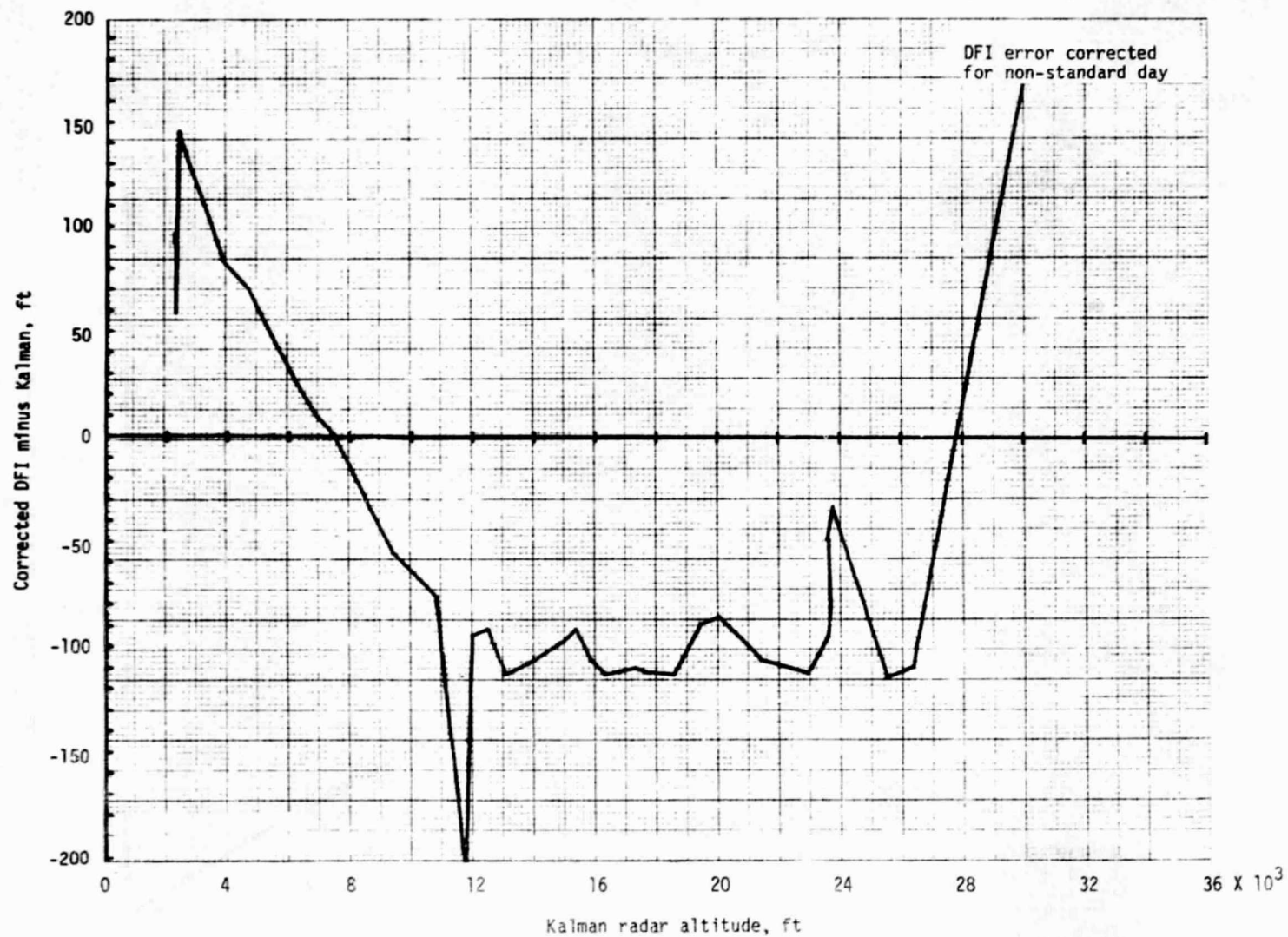


Figure B-26.- DFI error corrected for non-standard day (free flight 1).

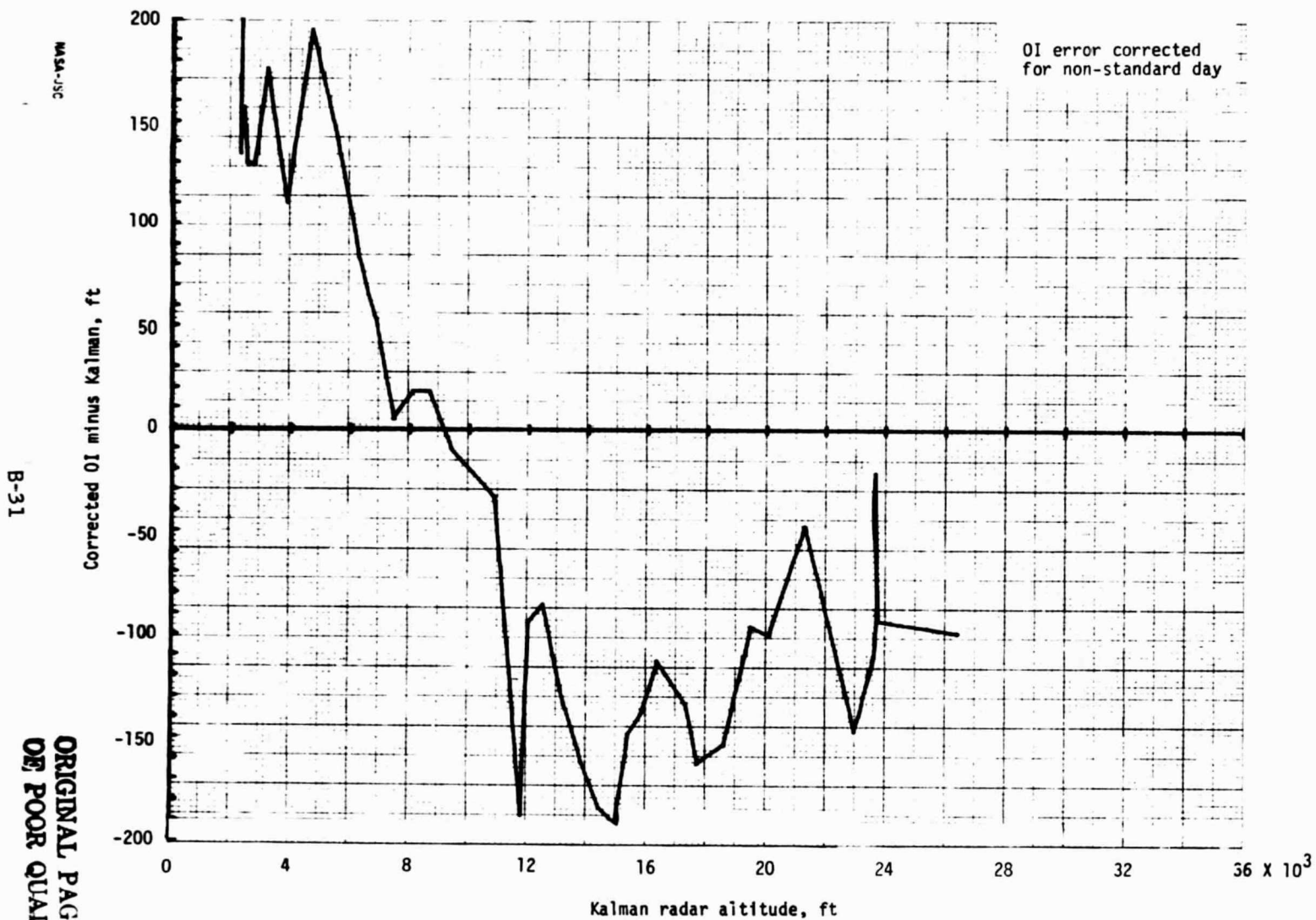


Figure B-27.- OI error corrected for non-standard day (free flight 1).